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Riparian buffer zones of the Ybytyruzu Mountain Range, Paraguay

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Riparian Buffer Zones of the Ybytyruzu Mountain Range, Paraguay

By

Wendy A. Owens

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN FORESTRY

MICHIGAN TECHNOLOGICAL UNIVERSITY

2003

The Report “Riparian Buffer Zones in the Ybytyruzu Mountain Range, Paraguay” is hereby approved in partial fulfillment of the requirement for the Degree of MASTER OF SCIENCE IN FORESTRY.

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Chapter 1 Introduction

In March of 2000, after being assigned to Paraguay, I developed a project to complete during my Peace Corps service in Paraguay. My interest revolved around stream ecology. I wrote a project proposal in my research methods class (FW 581). My initial objectives were focused on riparian vegetation, aquatic macroinvertebrates and physical characteristics of the streams in the Paraguay River watershed.

With this proposal in hand I went to Paraguay hoping to be placed in eastern Paraguay where the majority of the streams and rivers are found. I was placed in Santa Catalina, Colonia Independencia, Guaira found in the Ybytyruzu Mountain Range of eastern Paraguay. There are many small streams in Santa Catalina and community members were interested in water quality conservation. This realization of the human side to water quality issues changed my goal to study the watershed to help improve the land these people lived on. Santa Catalina along with other communities in the Ybytyruzu Mountain Range had many problems related to degraded riparian zones, soil erosion and poor stream water quality. These problems resulted from deforestation of stream banks and riparian zone conversion to pastures. These problems were not exclusively found in the Ybytyruzu Mountain Range but in many other communities in Paraguay.

La Reserva Nacional Recursos Manejado del Codillera Ybytyruzu is a national natural reserve designated by the government of Paraguay. The Paraguayan government and non-governmental organizations are interested in preserving the natural ecosystems of the Ybytyruzu Mountain Range. Santa Catalina is part of this reserve. There is little ecological information on the Ybytyruzu Mountain Range. Given the water quality issues the communities were concerned with and the little information on the ecosystems of the Ybytyruzu Mountain Range, I decided to study the watershed of Santa Catalina. The information I gathered will be important to not only the community members of Santa Catalina but to Paraguay's efforts in conservation.

Paraguay is a complex country with many different current and past issues defining current conservation practices. Chapter 2 discusses the general background on the history, the politics, and the natural ecosystems of Paraguay. The importance of the history of Paraguay will explain current views on conservation. I will discuss current conservation practices and special ecosystems found in eastern Paraguay.

Stream water quality and riparian buffer zones are concerns throughout the world and Paraguay is no exception. Chapter 3 discusses the importance of stream water quality and riparian buffer zones in general. Previous studies have shown the importance of riparian buffer zones and the techniques to determine the health of the riparian zone including the stream water quality. Watershed health is important in all parts of the world and this section discusses various manners to determine health of a watershed.

Chapter 4 gives the methods of the study and the raw data collected. The data collected came from riparian canopy coverage, diversity of aquatic macroinvertebrates, chemical analyses of the water and the stream discharge of eight sites at four streams. Descriptions of individual sites and of the streams are given.

Chapter 5 is the discussion of the results. My discussion emphasizes on overstory density, diversity of aquatic macroinvertebrates and dissolved oxygen concentrations in water. I also included an interesting trend in pH levels in some streams.

Chapter 6 discusses recommendations and conclusions resulting from the study conducted in Santa Catalina. In this chapter I will suggest recommendations for Santa Catalina, for any organization working in the Ybytyruzu Mountain Range, and for Peace Corps.

My main objective of this study is to gather baseline scientific information to aid in the proper management of the Santa Catalina watershed. This information can be used at a local level in the Ybytyruzu Mountain Range or throughout Paraguay as guideline to improve their conservation practices.

Chapter 2 Background

2.01 Paraguay

The Republic of Paraguay is a small landlocked country in South America surrounded by Bolivia, Argentina, and Brazil. Its center is located 23 degrees south and 58 degrees west (Figure 2.01). It is small country, approximately 406,750 square kilometers in size. It has a population of about 5,884,491 people as of July 2002 (CIA 2002). Paraguay's climate is subtropical to temperate. Eastern Paraguay has substantial rainfall while farther west the climate becomes semiarid. Paraguay has many rivers and streams throughout the eastern portions. About 9,450 square kilometers of the surface area contains freshwater. Rio Paranà and Rio Paraguay are the largest rivers.

Figure 2.01: Map of Paraguay

Source: www.cia.gov/cia/publications/ factbook/maps/pa-map.gif

Paraguay is a country of extraordinary natural beauty with lush forest, and meandering rivers and streams. Historically low population densities kept environmental degradation to a minimum. Major environmental problems have arisen in the last 50 years and the government of Paraguay along with non-governmental organizations are addressing the problems. Paraguayans are aware of the problems but do not know how to resolve them without consequences to their economic stability. Corruption and ignorance are the main culprits impeding the country from moving forward on these issues.

2.02 *History*

The country was discovered and settled by the Spanish in 1537. Paraguay declared independence from Spain on May 14, 1811. The Triple Alliance and the Chaco War were the two major disputes Paraguay had with Brazil, Argentina, Uruguay, and Bolivia. President Francisco Solano Lopez led Paraguay into the ill-fated Triple Alliance War. President Lopez ruled callously and killed anyone who made mistakes or opposed him. With his aggressive nature he foolishly led Paraguay into the war. The Triple Alliance War was fought against Uruguay, Argentina and Brazil from 1865 to 1870 (CIA 2002). The Triple Alliance War started with the invasion of Uruguay by Brazil. President Lopez felt an obligation to protect the small country from the bigger aggressor. Library of Congress (1988) Country Studies states President Lopez "assessed the September 1864 Brazilian intervention in Uruguay as a slight to the region's lesser powers". The Paraguayan Army had to travel through Argentina in order to help Uruguay. President Lopez asked permission to send troops through northern Argentina, unaware of Argentina's alliance with Brazil on the matter of Uruguay. Permission was not granted but Paraguay entered anyway. When this occurred Argentina and Brazil coerced Uruguay to form an alliance against Paraguay. This alliance began the downfall of President Lopez and his country. President Lopez and many of his men died on the battlefield near Argentina. A large portion of population later died of disease and starvation, making this the darkest period of time for Paraguay as nation (Library of Congress 1988).

During the Twentieth Century, the political climate began to change and the government became less stable. Between 1904 and 1954, there were 31 presidents in office. With the all the internal problems, Paraguay also had to deal with Bolivia as it tried to take land from the Chaco a region of western Paraguay. President Eusebio Ayala led Paraguay into the victorious Chaco War (Library of Congress 1988). This was the last major war Paraguay had with its neighbors, entering into an era of internal conflict but international peace and corporation with its neighbors.

Alfred Stroessnor forcibly obtained the Presidency in 1954 and became the last Paraguayan dictator. He ruled viciously, eliminating anyone who opposed him. He did several things to improve the country's infrastructure and worked with Brazil and Argentina on the Itaipua Dam to provide electricity to the country. In 1989 the people in the opposition party overthrew Stroessnor and established a free democracy (Library of Congress 1988).

The current government of Paraguay is a constitutional government. It was established in 1992. Political stability is tenuous. March of 1999 was one of the most violent times for the young democratic government. Violent clashes within the Colorado party resulted in Vice-President Argana's death along with six other prominent government officials and President Raul Cubas fled to Argentina. This resulted in the appointment of the current president, Luis Angel Gonzalez Macchi (CIA 2002; CNN March 29, 1999). In August 2000, vice-president Julio Cesar Franco of the opposition party was elected.

2.03 *Politics and Corruption*

The Colorados and the Liberals are the main political parties. The Liberals have not been in power since the late 1930's. Before the 2003 presidential race, the vice-president was a Liberal; his name is Julio Cesar Franco. Paraguay has many problems politically. For example, President Macchi is not popular with his country because he was never elected and only is president because the ruling party appointed him. The legislative branch tried to impeach him on February 12, 2003 but did not have enough votes. He was accused of misappropriation of funds, fraud, the torture of leftist militants and illegally buying a stolen BMW car. President Macchi was not impeached because to remove him from office would mean leaving the presidency vacant during a bad political situation (CNN.com February 12, 2003).

2.04 *Economy*

The economy is a market economy based on agriculture. Forty-five percent of the labor force works in agriculture. Paraguay acquires imports from Brazil, Argentina, and United States. The economy has been steadily becoming worse. Thirty-six percent of the population lives below the established poverty line of Paraguay. The unemployment rate is 17.8 percent and it may have risen since the collapse of the Argentinean economy in

2001. Prior to the Argentine economic collapse, some Paraguayans worked in Argentina and sent money back to their families. Since then, these Paraguayans have returned and some are unemployed (CIA 2002).

2.05 ***Commerce and MERCOSUR***

The major industries in Paraguay are sugar, cement, textiles, and beverages, which includes Yerba Mate (*Ilex paraguensis*), and wood products (CIA 2002). The major agriculture products of Paraguay are cotton, sugarcane, soybeans, corn, wheat, tobacco, mandioca (cassava), fruits, vegetables, beef, pork, eggs, milk, and timber. Paraguay has manganese, iron ore, and limestone mines of important economic value. The majority of the population has electricity available generated by the Itaipua Dam. This source of hydroelectric power provides electricity for Brazil, Argentina, and Paraguay(CIA 2002).

MERCOSUR is a trade agreement among Paraguay, Argentina, Brazil, and Uruguay. The agreement was signed in 1991. The objective of the agreement was to create a common market and lower taxes on imports and exports. It is similar to the NAFTA agreement with the US, Canada, and Mexico. Chile and Bolivia are negotiating agreements to be part of MERCOSUR. Other countries such as Peru and Ecuador are also considering talks in the future (IDRC January 3, 2001). Through this agreement, commercial traffic has increased among the countries.

2.06 ***Natural resources***

Paraguay has two distinct natural regions. The largest portion of Paraguay is the Chaco. It lays on the northwestern side the Rio Paraguay. The ecosystems are savanna-like and have very little rainfall. On the southeastern side of the Paraguay River, lies the Oriental Region or Eastern Paraguay. This is the most populated region. The ecosystems are mainly forested or grasslands. The highest point in Paraguay is found in the Ybytyruzu Mountain Range. The name of the highest point is Cerro Tres Kandu, at 842 meters. Cero Amor at 815 meters, and Cerro Capi'i at 816 meters are the next highest peaks in Paraguay found near Tres Kandu (Ibarra and Nunez 1998).

2.07 ***Deforestation in Paraguay***

In the last 25 years Paraguay has the highest rate of deforestation in Latin America. In 1945 eastern Paraguay had 8,805,000 hectares of forest and in 1991 the forested area was 2,403,000 hectares of forest (Nunez and Ibarra 1998). The rate of deforestation was about 212,000 hectares per year between 1968-1976 and between 1985 -1991 the rate was 290,000 hectares per year (Pinazzo 1996 as cited in Ibarra and Nunez 1998). The threat of deforestation comes from the illegal exportation of high quality lumber (Pinazzo 1996 as cited in Ibarra and Nunez 1998). Deforestation can also be attributed to free access settlement of landless peasants. The Forest Law of 1973 allowed the landless peasants to clear land for cultivation. The people of Paraguay view forests as a waste of land and the government wanted the forests to become used in agriculture allowing landless peasants to move into forested regions (Glastra 1999). According to the USAID (2002), "…Paraguay continues to lose 10% of its remaining original forest cover every year". USAID (2002) states the environmental problems aggravate poverty and threatens natural ecosystems. A plan to preserve the forests is imperative. People who have land and are becoming poorer as the economy deteriorates want to convert more forests to plant more crops. Consequently preservation of regions of high diversity and forest conservation education are necessary.

2.08 *Water Resources in Paraguay*

Numerous waterways within Paraguay are contaminated with garbage and domestic animal wastes. Residents of Paraguay, especially in densely populated regions dump their garbage in the streams and rivers. There are several reasons why Paraguayans dump their garbage in the streams and rivers. These reasons are mainly the lack of a centralized location to dump the garbage and the easy convenience to dumped it the nearby stream. The pollution is visible, making visitors wonder why the Paraguayans do not worry about their water resources. In the rural parts of Paraguay the children drink from the streams. Pesticides from the cotton fields or soaps used to wash clothes in the stream pollute these streams. The wells are not dug deep enough nor properly capped so the wells have high bacteria counts from animal or human feces. Some communities in the interior of Paraguay are in desperate need of treated running water. The source of clean drinking water is difficult to obtain in parts of Paraguay and Peace Corps is helping implement running water systems from aquifers instead of contaminated groundwater. Paraguay along with Brazil, Argentina and Uruguay are undertaking the water conservation issue by working together on the preservation of the Guarani Aquifer.

2.09 *The Guarani Aquifer and the Interior Atlantic Forest*

Santa Catalina, Colonia Independencia is found within the Interior Atlantic Forest and is on the rechargeable zone of the Guarani Aquifer. The Interior Atlantic Forest is an important ecosystem and the Guarani Aquifer is a major source of drinking water for Paraguay. Increased population densities threaten these systems. The Interior Atlantic Forest (Figure 2.02), a subtropical rain forest was once the size of Egypt (TVE 2000). The habitat is called Tropical and Subtropical Moist Broad Leaf forest (WWF 2003). It stretches across part of eastern Paraguay through the northeastern part of Argentina and through the southern part of Brazil (TVE 2000). According to the NGO Fundacion Moises Bertoni (2003) the Interior Atlantic Forest is considered to be one of the most diverse ecosystems on the South American continent and the most threatened in the world. This organization bought some of the remnants of the Interior Atlantic Forest to preserve and study. Since 1992, the original purchase of the land, there have been several publications on different species of tree, plants, animals, and research on the native Guarani indigenous people of what is now called the Mbaracayú National Reserve. Peace Corps has been working closely with this organization to help educate the people found in the Interior Atlantic Forest. They are teaching about the biodiversity and the best ways of preserving the forest. Peace Corps developed an environmental education-teaching manual. This manual can be used with school children or with community groups to help preserve the forest.

Figure 2.02: Interior Atlantic Forest

The Guarani Aquifer (figure 2.03) covers 1,200,000 km^2 in the eastern and south central portions of South America: Argentina, Brazil, Paraguay, and Uruguay. It is considered one of the world's largest freshwater underground reservoirs (World Bank 2003). It holds 48,000 cubic kilometers of freshwater and 360 million people can benefit from the freshwater supply (Connor 2002).

Figure 2.03 Map of Guarani Aquifer

2.10 *Colonia Independencia.*

The Municipality of Colonia Independencia is a large region on the northern edge of the Ybytyruzu Mountain Range in the Department of Guaira. Villarrica, the capital of Guaira, is on the southern side of these mountains. The capital of Colonia Independencia is Melgarejo, a small German colony. The surrounding countryside is settled with *mestizo* Paraguayans. The region was settled in the early 1900's and in the 1950's remote places like the Santa Catalina (Ibarra and Nunez 1998). The German colonists are the largest landowners. The German farmers cultivate corn, sugarcane, cotton and graze cattle. Grapes are grown for a small wine industry. The Paraguayan peasants living in Colonia Independencia are descendents of the Germans or other *mestizo* citizens from other parts of the country. The Paraguayans in Colonia Independencia own between 5 and 60 hectares of land. Many of these farmers plant for their own consumption. The main subsistence crops are corn, cassava, beans, sweet potatoes and peanuts. Sugarcane and cotton are the main cash crops with organic sugarcane becoming more prominent. The Department of Guaira has several sugarcane factories providing cheap and easy access for the farmers to sell their product. This region of Paraguay has relatively fertile soil for agriculture and provides excellent land for the cultivation of organic sugarcane. Several farmers are following guidelines to certify their sugarcane as organic. To be certified farmers cannot burn the fields after harvest, a farmer cannot use pesticides nor use chemical fertilizers. Planting green manure with organic sugarcane is a new technique to aid in fertility in the absence of chemical fertilizers.

2.11 Santa Catalina

In the 1950's Pedro Cazal, Pantaleon and Castor Galeano, and Raimundo Soto settled Santa Catalina. These four men settled in Santa Catalina at the base of the Ybytyruzu Mountains (Figure 2.04) and cultivated many different types of crops on 40 to 50 hectares of land each. I spoke to two of these men about their early experiences. Pantaleon Galeano and Raimundo Soto both describe vast forests mixed with bamboo (*Bambusa guadua*) and many wild animals including big cat species called Jaugaurete (*Pamthera onca).* Other species include smaller cats like *Tirika* (*Leopardus wiedii).* People from the cities come into the area to hunt and log trees like *Tajy* (*Tabebuia impetiginosa*). This tree is threatened due to its high economic value. *Tajy* is the national tree and has a unique purple flower and blooms in August. It is beautiful tree and the Paraguayans take pride in it. Now Paraguayans preserve this tree and are actively planting it on their property.

Figure 2.04 Santa Catalina Cerro Primo Amor.

Despite people coming into the Ybytyruzu Mountain Range to hunt and take out natural resources, the low population density has helped maintain high biodiversity. (Ibarra and Nunez 1998). Santa Catalina has animals on the endangered species list of Paraguay. Some of the animals are scarce in the northern parts Paraguay (Table 2.01). The habitats of these animals are being destroyed by deforestation and fragmentation of the landscape. No wildlife study has been conducted in the Ybytyruzu Mountain Range (Esquivel 2001).

Table 2.01: Animals Found in the Mbaracayu Reserve and Are Present Ybytyruzu Mountain Range

English Name	**Common Name**	**Scientific Name**
Armadillo	Tatu Hu	*Dasypus novemcinctus*
Armadillo	Tatu poju	*Euphractus sexcintus*
Armadillo	Tatu ai	*Cabassous tatouay*
Deer	Guasu pyta	*Mazama americana*
Deer	Guasu vira	*Mazama gouazoubira*
Monkey	Ka'i	*Cebus apella*
	Kuati	*Nausa nausa*
	Eira	*Eira barbara*
	Lobo pe	*Lontra longicaudis*

Source: Esquivel (2001)

Santa Catalina residents obtain their potable water from either hand-dug wells or springs. Some families have dug shallow wells prone to drying up in droughts and others dug wells through rock to reach a deeper source of water. Most families obtain potable water from springs found along the various little streams. In most cases the first settlers obtained water from springs. Pantaleon Galeano has a spring 150 meters from his house next to a small stream. This spring was used until he hand dug a well close to the house. The spring is not in use unless the well dries up and this occurs, on average, once a year. The Soto family use springs found on their property. The Cazal family also used a spring until recently when they had wells dug near the house. The spring is one of the bigger springs in Santa Catalina. The elementary school used this spring until recently when a well was dug and a running water system was implemented. As the population of Santa

Catalina grew, less desirable land was available. The land closer to the base of the mountains is the least desirable not only for agriculture but also for the lack of drinking water.

2.12 *Ybytyruzu Mountain Range*

The Ybytyruzu Mountain Range is found in the middle of Eastern Paraguay within the departments of Guaira and Caazpa (Figure 2.05). It encompasses approximately 30,000 hectares (Ibarra and Nunez 1998).

Figure 2.05: Ybytyruzu Mountain Range

Santa Catalina is found in the Ybytyruzu Mountain Range. The soils in the Ybytyruzu Mountain Range are considered entisols (Ibarra and Nunez 1998). The parent material is usually basalt or sandstone (Ibarra and Nunez 1998). The parent material in Santa Catalina is basalt. Some soils in Santa Catalina are sandy, indicating sandstone is present upslope of site (Boul *et al.* 2003).

Many tree species are found in the Ybytyruzu Mountain Range and in Santa Catalina. Ibarra and Nunez (1998) identified seventeen tree species (Table 2.02).

Table 2.02: Tree Species in the Ybytyruzu Mountain Range

Common Name	**English**	**Scientific Name**
Tajy	Purple Trumpet Tree	*Tabebuia impetiginosa*
Tajy Hu	Pink Trumpet Tree	*Tabebuia heterophylla*
Yvyra Pyta	Copper pod	*Peltophorum dubium*
Petereby		*Cordia trichotoma*
Incienso		*Myrocarpus frondosus*
Yvyra Ro		*Pterogyne nitens*
Guayavi		*Patagonula americana*
Aratiku	Similar to Cherimoya	*Rollina emarginata*
Timbo	Paraca earpod tree	*Enterolobium contortisiliquum*
Kurupa'yra		*Parapiptadenia rigida*
Cedro	Spanish Cedar	*Cedrela fissilis*
Amba'y	Matchwood	*Didymopanax morototoni*
Tuna	Cactace	*Cereus coryne*
Takuara	Bamboo	*Bambusa guadua*
Inga	Banana inga	*Inga uruguensis*
Yvyra ita		*Lonchocarpus leucanthus*
Koku (Koky)		*Allophylus edulis*

Table adapted from information found in Ibarra and Nunez (1998) and Peace Corps publication *Nande Yvyra mata* undated.

In addition to several native trees, the residents of the area have interesting agroforestry systems incorporating six exotics and fruit trees (Table 2.03).

Table 2.03: Agroforestry trees used in Santa Catalina

Common Name	**English name**	**Scientific name**
Leucaena		*Leucaena leucocephala*
Apepu	Sour Orange	*Citrus aurantium*
Hovenia	Japanese Raisin Tree	*Hovenia dulcis*
Avocate	Avocado	*Persea sp.*
Mamon	Papaya	*Carica papaya*
Mango	Mango	*Mangifera indica*

The NGOs working in the Ybytyruzu Mountain Range have noted it as a place with extraordinary biodiversity (Ibarra and Nunez 1998). Yet, the proposed preservation of the Ybytyruzu Mountain Range has caused controversy. Several organizations have wanted the Ybytyruzu Mountain Range to be a national park. Since the area is populated, the government, with pressure from NGOs, has changed the name to National Managed Reserve of the Ybytyruzu Mountain Range. Many residents within the Reserve are unhappy with this for several reasons. The most prominent reasons are the restrictions which prevent the farmers from clearing more land to help their family economically. Farmers cannot burn fields, harvest trees, or clear land for cultivation. These restrictions are not acceptable to many and the communities found within the reserve are working together to come up with guidelines to prevent deforestation and provide a better environment. Residents are encouraged to plant trees to reforest the land. The original organizations have faded to the background and community leaders have taken control.

Chapter 3 Research Background

3.01 *Study Site*

Santa Catalina, Colonia Independencia is a community within the Interior Atlantic Forest. Santa Catalina is in the Ybytyruzu Mountain Range and the watershed sits upon the rechargeable Guarani aquifer. The importance of this study is to get baseline information to understand the water quality issues in the Ybytyruzu Mountain Range. Santa Catalina has problems with erosion, sedimentation and nutrient enrichment of its streams. The terrain in Santa Catalina is hilly providing ideal conditions for erosion. When the landowners clear land to the stream banks, destabilization of the stream banks occur allowing erosion from the farm fields to enter the streams making the water turbid. Pastures along the streams increases the amount of nutrient loading from animal wastes. Many residents obtain their drinking water from springs found near these streams and in some cases after high amounts of rainfall, the springs are flooded by the stream along with contamination from sedimentation, animal wastes and pesticides.

The study area encompasses five streams with three tributaries of a larger stream on the eastern edge of Santa Catalina and one stream on the western edge of Santa Catalina. Santa Catalina has a mixture of forest and farmland (Figure 3.01). A few dirt roads and about 50 households are present in an area of about 25km^2. The terrain is hilly with sandy or red clay soil types. The soil is classified as an entisol (Ibarra and Nuñez 1998). The streams have steep banks preventing farmers from cultivating to the banks of the stream. The streams are an important part of the Ybytyruzu Mountain Range for the clean drinking water which they provide. Healthy watersheds are important in all parts of the world and researching crucial ecosystems is important to acquire pertinent information to implement practical management strategies.

Figure 3.01 Santa Catalina: View from a hill

3.02 ***Background research***

Streams are excellent ecosystems to study. Streams have defined boundaries and the simple scientific techniques to gather data are repeatable throughout the world (Power 1988). Streams are vulnerable to anthropogenic disturbances. In both temperate and tropical regions, deforestation causes changes in the chemical and physical attributes of streams (Power *et al*. 1988). Since there is worldwide need to understand watersheds and water quality, retrieving baseline information on a small system in Paraguay can add to the knowledge of these systems.

The Santa Catalina watershed is considered a headwater system because it is an "area from which water originates within a channel network." Headwater systems "are characterized by interactions among hydrologic, geomorphic, and biological processes that vary from hillslopes to stream channels and from terrestrial to aquatic environments (Hack and Goodlett 1960 as cited in Gomi *et al.* 2002). Headwater systems are important to downstream processes, protecting the whole watershed. Understanding water quality of the whole watershed requires knowledge of the headwater stream. Society underestimates the importance of headwater systems because of their small size. In Santa Catalina many ignore the tiny streams and farm around them. These small streams can affect the larger rivers (Gomi *et al.* 2002).

Water quality and land use issues are important in all parts of the world. Water quality can be measured through biomonitoring, riparian buffer widths and chemical Analyses of the water (Carter and Resh 2001). Other studies on stream ecosystems have considered aquatic macroinvertebrates as bioindicators for water quality (Rosenberg and Resh 1993, Zweig and Rabeni 2001; Carter and Resh 2001; Kay *et al.* 2001; Eaton and Lenat 1991; Wallace *et al.* 1996.). Riparian buffer zones are an important component to water quality because of the interaction between the terrestrial and the aquatic ecosystems. Riparian vegetation have the ability to take up excess nutrients, therefore reducing nutrient loading of the stream. (Newbold *et al.* 1980; Gregory *et al.* 1991; Thompson R.M. and Townsend, C.R. 2000). Chemical analyses and physical attributes of the stream are important when combined with macroinvertebrate sampling (Kay *et al.* 2001).

3.03 *Riparian Buffer zones*

Riparian zones are interfaces between terrestrial and freshwater ecosystems. Riparian zones are also places of high diversity and unusual environmental processes (Naiman and Decamps 1997; Gregory *et al.* 1991). They play an important role in stream ecosystems, influencing habitat complexity, nutrient cycles and biodiversity (Cooper *et al.* 1995, Naiman and Decamps 1997). Riparian plant communities control the amount of nutrients entering the stream by using the nutrients needed. Cooper *et al.* (1995) states “careful management of riparian zones” can allow buffering of streams from poor land use. Muscutt *et al.* (1993) state buffer strips act as filters for sediments and nutrient runoff from agriculture. With this information Cooper *et al.* (1995) tested whether riparian buffers can act as a deterrent of non-point source pollution. The absence of riparian vegetation may result in surface runoff containing higher concentrations of phosphorus or nitrogen. Cooper *et al.* (1995) conclude riparian buffer zones can retain pollutants such as phosphorus and nitrogen. Phosphorus runoff into the streams is slowed by the buffer strips (Franklin *et al.* 2002; Fang *et al.* 2002). Several scientific studies compare riparian buffer zones and the effects of grazing by domestic animals and logging (Davies and Nelson 1994; Brosofske 1997).

Fluvial processes as well as geomorphic processes shape riparian zones and these systems provide critical physical and biological linkages between the terrestrial and stream components of the ecosystem (Gregory *et al.* 1991). Thus collecting data on stream discharge and other physical attributes can provide crucial information on water quality linked to riparian zones.

Paraguay has no studies similar to those discussed. It is obvious how important riparian buffer strips are and the importance should not diminish even though the natural ecosystem of Santa Catalina is the Interior Atlantic forest. Fundamental ecological principles apply regardless of location.

3.04 ***Biological Monitoring***

Aquatic macroinvertebrates are useful in the study of freshwater ecosystems because of their relatively long life spans, their sedentary state, ease of sampling when compared to fish, and more information on these organisms, thus, making it easier to use them as biological indicators of water quality. There are several taxa, which are well known for their sensitivity, and therefore the absence or present of these commonly found aquatic macroinvertebrates could allow for accurate analyses (Rosenberg and Resh 1993;Quinn and Hickey 1990; Shieh and Yang 2000). Aquatic macroinvertebrates are difficult to study because identification to the species level is not easy. Therefore in many studies, which incorporate insects, categorize each individual by its morphological features (Barger and Esch 2002; Allan *et al.* 1973; Basset 1996). Certain aquatic macroinvertebrates are sensitive to slight changes in their ecosystem. Due to the high sensitivity to dissolved oxygen concentrations and nutrient loading of certain aquatic macroinvertebrates, these organisms are not found in polluted freshwater systems.

Biological monitoring is an important method for recording trends over a period of time in an aquatic system. Long-term monitoring of an aquatic ecosystem can record inputs of pollution by industry or agricultural runoff. The objective of biomonitoring is to gather baseline data and continue periodically gathering data to see if any changes have occurred. In the last 25 years, many scientists have noted the importance of biomonitoring (Worf 1980; Cairns 1980; Lenat *et al.* 1980; Rosenberg and Resh 1993; Loeb and Spacie 1994; Cairns and Pratt 1993). Aquatic macroinvertebrates are used in biomonitoring techniques and frequently used to assess water quality. Water quality changes in a freshwater ecosystem are reflected in the aquatic macroinvertebrate population. Biomonitoring provides crucial information in stream water and habitat quality. Aquatic macroinvertebrate composition responds to changes in sedimentation, nutrient loading and dissolved oxygen concentrations (Kaishan and Burton 2000; Manny 1991; Weiderholm, T. 1984; Lenat *et al.* 1980; Rosenberg and Resh 1993). Genetic composition, measurements of changes in population numbers, community composition or ecosystem functioning are use to monitor changes in aquatic macroinvertebrates composition (Rosenberg and Resh 1993).

To evaluate aquatic macroinvertebrate data, several techniques are used depending on habitat structure. Ephemeroptera, Plecoptera, and Tricoptera (EPT) measures taxa richness when compared to more traditional diversity indices (Eaton and Lenat 1991). These include using indicator organisms or communities such as EPT (Eaton and Lenat 1991; Resh and Jackson 1993; Lydy *et al.* 2000; Morse 1980) and diversity or biotic indices (Lenat and Folley 1983; Resh and Jackson 1993). The EPT technique is described in Resh and Jackson (1993) and it is a technique "where the Ephemeroptera, Plecoptera, and Trichoptera are separated from the other macroinvertebrates by order, the number of distinct taxa is then counted." Another useful technique described by Resh and Jackson 1993 is the ratio of EPT abundance to Chironomidae abundance. The technique requires counting all the taxa found in the orders of Ephemeroptera, Plecoptera, Trichoptera, and Chironmidae families. The Chironmidae family is pollution tolerant when compared to the Ephemeroptera, Plecoptera, and Trichoptera orders. An imbalance among the taxa weight towards Chironomidae may indicate a stressed environment (Resh and Jackson 1993; Lenat and Folley 1983).

3.05 *Chemical and Physical Analyses*

Chemical analyses can help identify pollution problems. Oxygen and pH are important to water quality and organisms, as is temperature. Oxygen is important for aquatic life and is taken in as dissolved oxygen. Oxygen sources are the atmosphere or from photosynthesis from plants in the water. If livestock or human waste is introduced, algae and heterotrophic organisms become more abundant. This causes increase consumption of dissolved oxygen by decomposition or respiration. Dissolved oxygen should not be less than four parts per million for warm water environments. Anything lower can cause fish kills (Renn 1970). Low oxygen (less than 4 ppm) and pH less than 5.5 or higher than 8.5, can result in lower diversity of macroinvertebrates and other aquatic animals (Renn 1970). Several studies include dissolved oxygen concentrations and pH of water analyses as part of the baseline information along with other analyses within rivers and streams (Voelz *et al.* 2000; Kay *et al.* 2001). The relative acidity or alkalinity of water is measured as pH and this can affect the type of ecosystem and organisms found in streams. Most freshwater systems have a pH between 5.0 and 8.5. Sudden changes in pH can occur if contaminants are found in the system. Small changes, 0.3 or less, can still indicate a change in water quality (Renn 1970).

Stream discharge and analyses of other physical attributes are important in the Analyses of aquatic animals and chemical analyses (Kay *et al.* 2001). Physical disturbances also are directly linked to changes in population structure or resource availability (Death and Winterbourn 1995; Power *et al.* 1988). Severe disturbances (*e.g.* increase stream discharge) can lower diversity but little is known about smaller disturbances (Death and Winterbourn 1995).

3.06 *Diversity*

Diversity indices are tools to reflect composition of biota in a stream or river (Lydy 2000). Studies may use different types of diversity indices. Some measure species richness and others species evenness. It is used as a quantitative measure. It can be used to compare among sampling sites within a system. The Shannon indices are most commonly used (Zar 1999).

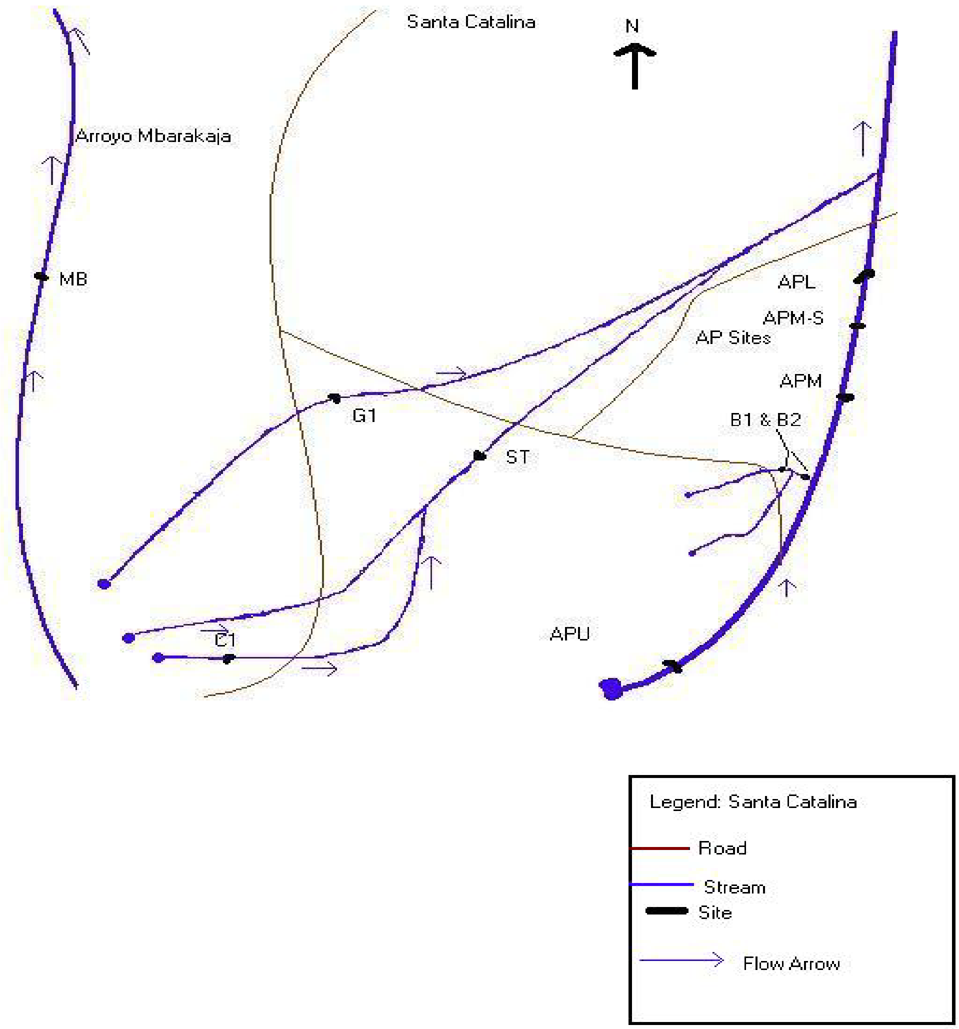
Chapter 4 Methods and Data

The objective of this study is to gather baseline scientific information on the Santa Catalina watershed. In this section, I describe the natural characteristics of the riparian and stream areas of each site. Then I describe my sampling methods on overstory density, chemical analyses, physical analyses, fish and aquatic macroinvertebrate sampling, and land-use interviews. This information can aid in proper management of the Santa Catalina watershed along with other watersheds in the Ybytyruzu Mountain Range.

4.01 *Sampling sites*

Five streams were selected for analyses within the Santa Catalina watershed. Preliminary data were gathered within the watershed during the first year of my Peace Corps service. After eight months of preliminary investigations eight sites were selected for analyses. Data were gathered on overstory density, chemical analyses of water, stream discharge, air and water temperature, insects, fish, and arthropods. Figure 4.01 shows the community and the streams. Table 4.01 shows the streams and the labels that were assigned to each site.

Figure 4.01Map of Santa Catalina



Approximate scale 1:20,000

Table 4.01: Stream sites

Stream	Sites
Arroyo Porâ	AP:(APL, APM, APM-S) APU
Arroyo Mbarakaja	MB
North of C1, ST	G1
South of G1, ST	C1
Downstream from C1	ST

The largest stream is Arroyo Pora. It is located near the eastern boundary of Santa Catalina. The AP sites are labeled as APL, APM, and APM-S; and the Arroyo Porâ upper is labeled as APU. The next largest stream is Arroyo Mbarakaja and is located on the western boundary of Santa Catalina. One site was on this stream. Three stream sites within the boundaries of Santa Catalina are in the southern section. These were the C1 site, the G1 site, and ST site. These sites are relatively close to each other. The G1 stream merges with the ST site stream. The C1 site stream merges with another stream to become the ST site stream. Data were gathered at preliminary sites. B1 and B2 are to the south of the other sites and, Arroyo Capi'i (AC) and Arroyo Guazu (AG) are to the east and to the west of Santa Catalina respectively. These sites were eliminated from the final round of data collecting due to the difficulty of access. Accessibility depended on the landowners. The situation in my community was volatile. Problems within the community made it difficult to continue my analyses on certain properties. An NGO, Alter Vida, wanted to convert the region into the Ybytyruzu Managed Reserve. A few community members felt this organization was conspiring to throw them off their property and they felt that I was part of this conspiracy. Hence, to circumvent further conflict, I avoided that part of the community in 2002.

4.01.1 *Arroyo Porâ*

Arroyo Pora is a medium size stream relative to the other streams in Colonia Independencia. The name of the stream is translated as “beautiful stream” from Guarani. It has average widths varying from 2.9 meters to 7.2 meters. Table 4.02 displays the average width and depth for each site on this stream analyzed. This stream enters Arroyo Capi’i, a river to the east of Santa Catalina.

Table 4.02: Average Widths and Depths

Stream	**Date**	**Average Width (m)**	**Average Depth (m)**
APM	5-Feb-02	4.54	0.21
APL	28-Jan-02	6.64	0.64
APM	10-May02	4.77	0.19
APM-S	4-Sep-02	3.53	0.13
APM-S	2-Dec-02	4.44	0.20
Range		3.53-6.64	0.13-0.64

The substrate of the stream is composed of pebbles and bedrock. Many boulders and rocks are present in the upper reaches of the stream (Figure 4.02c). It is a second order stream (Hauer and Lamberti 1996). The stream starts in Ybytyruzu Mountains between Cerro del Amor and Primo Amor. The stream is ephemeral in the mountains and gradually gains strength from springs and surface runoff as the stream travels downhill. The riparian zone is very steep and one waterfall is found in the upper reaches of this stream. The native vegetation consists of trees, shrubs and bamboo. As the stream enters the community, the riparian zone becomes more degraded in some parts(Figure 4.02a and Figure 4.02b).

Figure 4.02a: Typical Riparian zone near Arroyo Porâ. The riparian zone has minimal disturbance. Grazing is away from the stream

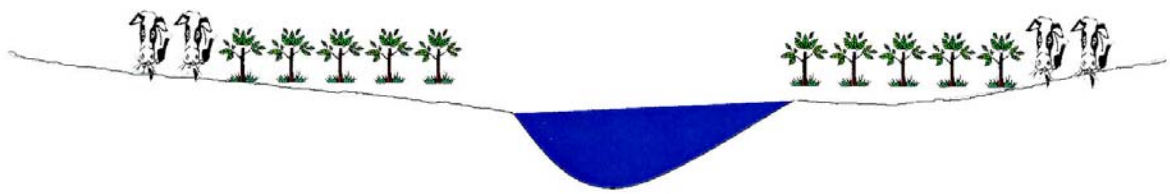


Figure 4.02b: Mixed pasture and forest along many streams. Riparian forest is degraded and cattle grazing is interspersed in the riparian zone.

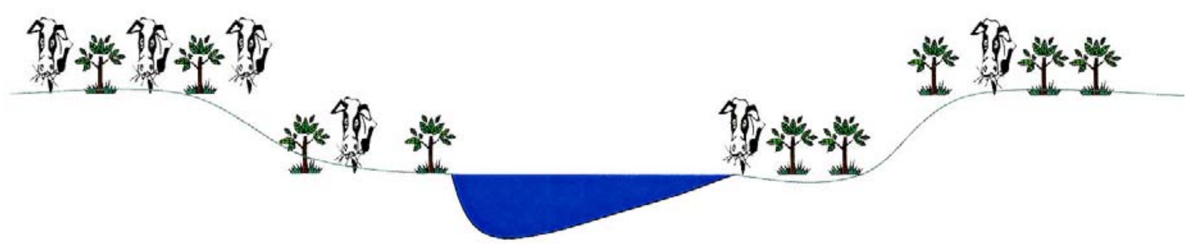


Figure 4.02c: Arroyo Porâ Lower sections

Agriculture predominates in the landscape. Cattle pastures (Figure 4.03) are more frequent along the stream. Pastures consist of a mixture of trees and open grassy meadows. Some of the riparian zones are steep and difficult to use for cultivation, consequently the riparian buffer zone is more extensive. The stream becomes wider as it travels downstream. Below the lowest stream site a dirt road intersects the stream. Without a bridge present, the road erodes into the stream causing some sedimentation. Beyond the study sites the stream riparian zone becomes more mixed with farms and smaller buffer zones. The stream winds down into the next community and the banks are exposed more frequently and smaller buffer zones perpetuate erosion of the sandy soils. The stream enters Arroyo Capi'i in the community of San Antonio near the main municipal road.

Figure 4.03 Cattle pasture near stream

4.01.2 *C1 site*

This site is upstream from the ST stream site. This stream merges with one other small stream to become the ST stream. The riparian zone of the C1 site has been converted to pasture and few trees are left (Figure 4.04). Inputs of soil and animal manure are noticeable. Sporadic vegetation growth is present along the stream, usually dense stands of young trees. The width of the stream varies between 0.69 meters and 1.52 meters. Table 4.03 shows the average widths and depths.

Figure 4.04: C1 site stream with pasture.

Table 4.03 Width and Depth of C1 stream site

Stream	Date	Average Width (m)	Average Depth (m)
C1	15-Feb-02	1.52	0.25
C1	16-May-02	1.16	0.09
C1	7-Nov-02	1.09	0.09
C1 (shade)	7-Nov-02	0.69	0.07
C1	02-Dec-02	1.11	0.12
Range		0.69-1.52	0.07-0.25

4.01.3 *G1 Site*

The G1 site is within a forested pasture. The stream originates in Santa Catalina, perhaps one kilometer from the G1 site. The stream is a small stream that has both wide and narrow buffer zones depending on the landowner (Figure 4.05). Rainstorms cause dramatic changes in stream discharge. Table 4.04 shows the width and depth averages.

This stream has various land uses along the banks. The G1 site had a wide riparian buffer zone but downstream the riparian zone was deforested to the banks of the stream.

Figure 4.05: G1 stream site

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Table 4.04: G1 Stream size

Stream	Date	Average Width (m)	Average Depth (m)
G1	28-Jan-02	0.65	0.09
G1	29-Jan-02	1.74	0.15
G1	6-May-02	0.71	0.09
G1	20-May-02	1.31	0.13
G1	17-Sep-02	0.59	0.09
G1	8-Nov-02	0.66	0.08
Range		0.59-1.74	0.08-0.15

4.01.4 *Arroyo Mbarakaja*

Arroyo Mbarakaja starts in southwestern part of Santa Catalina and it travels along the western boundary of the community. The name of this stream is translated as "the Cat Stream" from Guarani (Figure 4.06). The substrate in the riparian zone is sandy and the stream bank erodes easily. The site is labeled as MB. The site is found within a cattle pasture and used for drinking water for the cattle. The banks within the pasture are severely eroded. Several inches of sand are present in the benthic layer. It is a smaller stream than Arroyo Pora. The average width is between 0.5 meters to 1.3 meters (Table 4.05). The stream becomes wider as it reaches the municipal road. Upstream of the pasture, the banks are steep and surrounded by sour orange trees. Sour orange (*Citrus aurantium)* is a naturalized exotic species and has been in Paraguay for over 500 years. There are times when the oranges clutter the stream and water is more acidic for this reason (Table 4.06).

Figure 4.06: Arroyo Mbarakaja: School boy retrieving minnow traps.

Table 4.05 Averages for Width and Depth Arroyo Mbarakaja

Stream	**Date**	**Average Width (m)**	**Average Depth (m)**
MB	13-Feb-02	1.10	0.13
MB	5-Jun-02	1.19	0.18
MB	22-Oct-02	0.96	0.11
MB	25-Nov-02	1.06	0.09
Range		0.45-1.33	0.06-0.18

Table 4.06 pH of Arroyo Mbarakaja

Stream	**Date**	**pH**
MB	13-Feb-02	7.5
MB	5-Jun-02	7.1
MB	22-Oct-02	6.9
MB	4-Nov-02	7.5
Range		6.9-7.5

4.01.5 *ST Site*

This site is a mixed forest and pasture with few domestic animals present in the pasture. The stream banks are forested with an exception of 25 meters along the stream bank. A small trail crosses the stream and there is an opening in the canopy at that location (Figure 4.07). A charcoal kiln is present on the south side of the stream (Figure 4.08). The kiln is used sporadically during the winter months. The charcoal residue is thrown down the bank. Downstream of this site the riparian zone is forested and the stream becomes wider. The stream width varies from 0.8 meters to 4 meters during storm flow (Figure 4.09). Depth varied from 0.11 and 0.26 meters where the highest was during a period of intense rain (Table 4.07). The ST site stream merges with the G1 site stream. After the two streams merge, it enters Arroyo Pora.

Figure 4.07: ST site

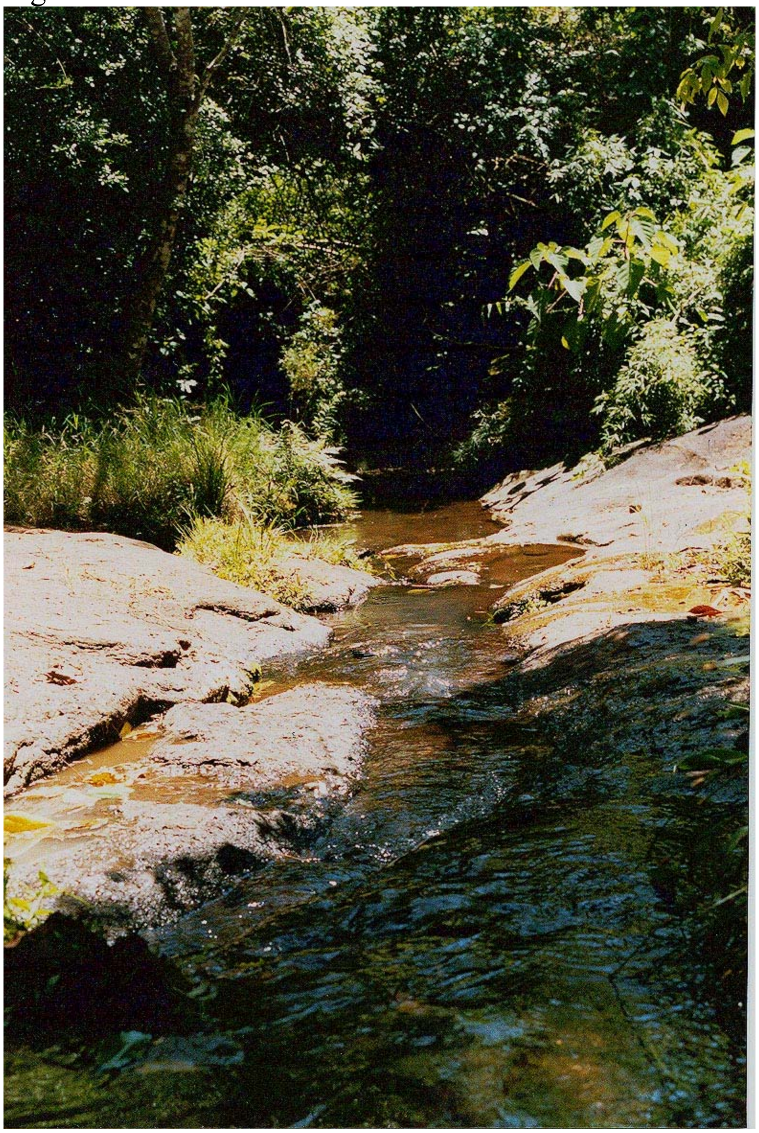


Figure 4.08: ST site Charcoal Kiln

Figure 4.09: ST storm flow

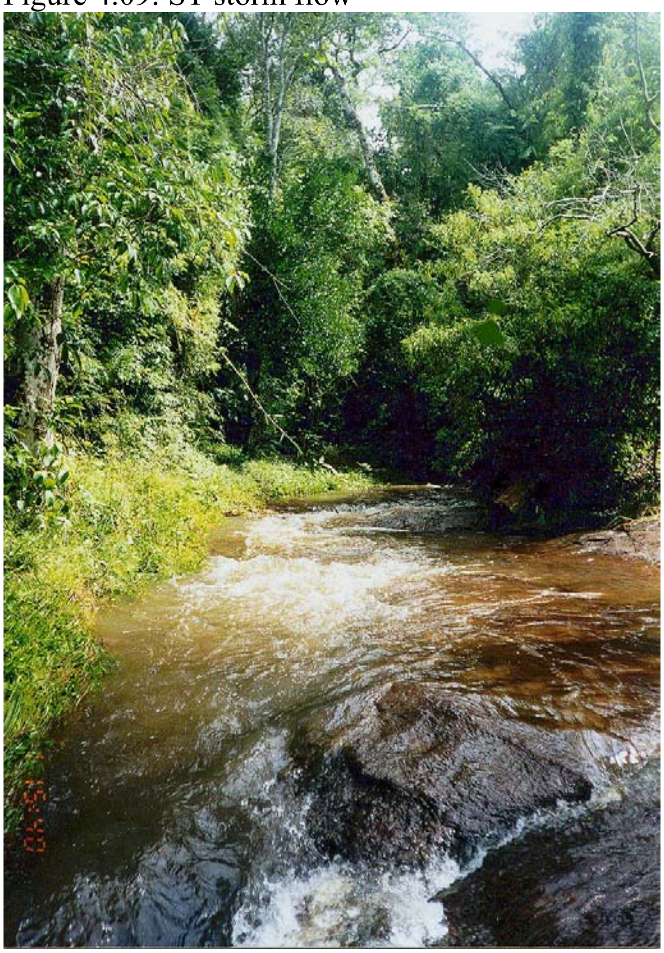


Table 4.07: Average Width and Depth of ST Site

Stream	**Date**	**Average Width (m)**	**Average Depth (m)**
ST	29-Jan-02	4.03	0.26
ST	3-May-02	0.89	0.12
ST	5-Sep-02	0.85	0.13
ST	8-Nov-02	0.82	0.12
Range		0.82-4.03	0.12-0.26

4.01.6 *Preliminary sites*

B1 and B2 sites are streamlets originating 300 meters from Arroyo Pora. These streams are very small and the sites are found in a pasture. Two rivers outside of the Santa Catalina watershed were analyzed to provide baseline information. Arroyo Capi'i (Grass stream in Guarani) and Arroyo Guazu (Big stream in Guarani) are the drainage points for the streams in my study area (Figure 4.09)

Figure 4.10: Arroyo Guazu

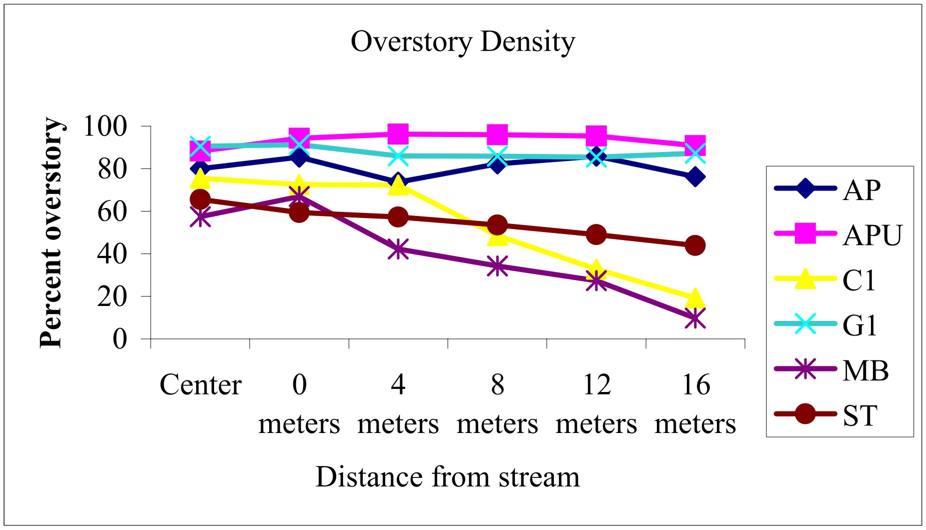
4.02 *Overstory Density*

Overstory density was measured with a spherical densiometer (Lemmon 1957). Sixteen transects were placed perpendicular to the stream bank. Both sides of the stream were analyzed up to sixteen meters from the bank. Readings were taken from the center of the stream, at zero meters (bank side), at four meters, at eight meters, at twelve meters and at sixteen meters. Transects were measured initially with a tape measure and then by pacing four meters at a time. In some riparian zones, transects were completed using extrapolations. Appendix 1.01 shows the data on overstory density on all sites. Table 4.08 shows the averages at each stream site and Figure 4.11 depicts the comparison.

Table 4.08 Average Percent Overstory Density (N=16)

Site	Center	0 meters	4 meters	8 meters	12 meters	16 meters
AP	79.98	85.40	73.64	82.20	85.86	76.21
APU	88.21	94.23	96.27	96.01	95.41	90.90
C1	75.56	72.48	72.28	48.53	32.83	19.31
G1	90.51	91.29	85.98	85.90	85.44	87.22
MB	57.49	66.92	42.30	34.27	27.39	9.72
ST	65.62	59.34	57.34	53.46	49.01	43.96

Figure 4.11: Overstory Density Comparison



4.03 *Chemical Analyses*

All sites were analyzed for pH and oxygen. LaMotte Chemical kits were used for the analyses (Campbell *et al*. 1992; Renn 1970). Dissolved oxygen concentration was determined by titration using predetermined chemicals provided by LaMotte Chemical (Campbell *et al*. 1992) and concentration was determined to 0.1. pH was determined by using a color indicator, than compared against a standard which could be determined to 0.5. Oxygen and pH were tested in all the streams in four seasons late summer, autumn, winter, and spring. Phosphorus and nitrogen were measured as negligible. pH was taken more frequently by sampling at various points around the site. Appendix 2.01 shows chemical analyses done at each site. Figure 4.12 and Figure 4.13 display a comparison of each site for oxygen and pH.

Figure 4.12: Dissolved oxygen averages (n=5)

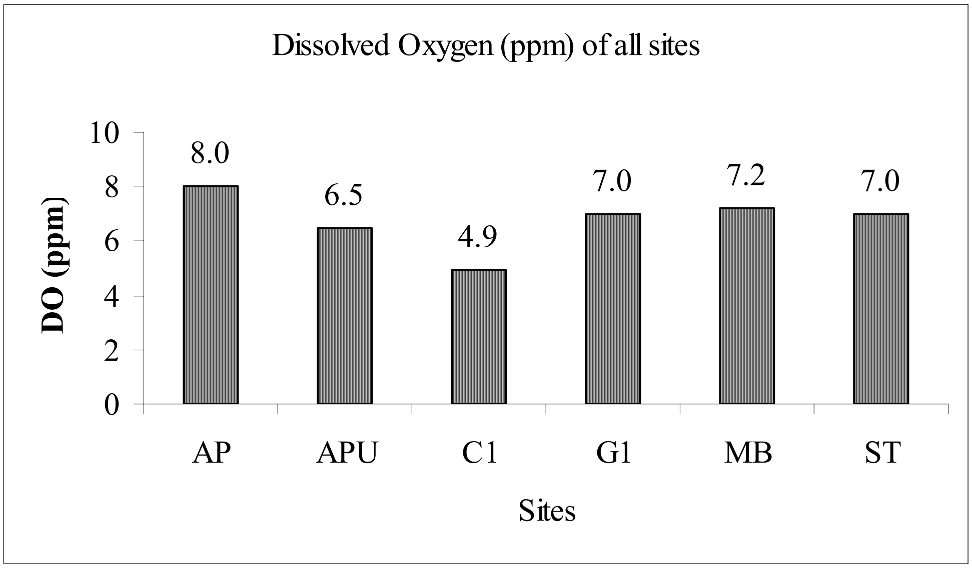
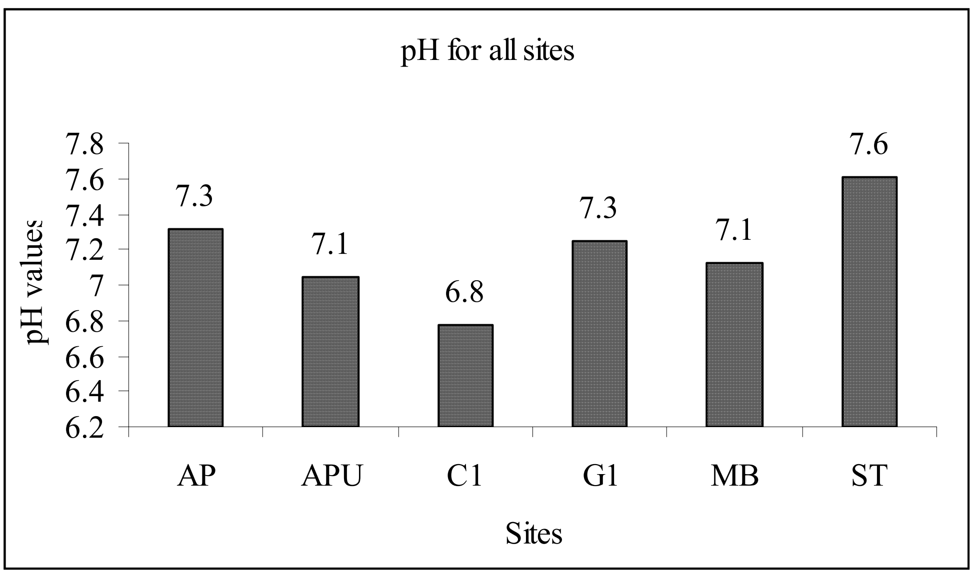


Figure 4.13: Comparison pH (n=10)



4.04 *Physical analyses*

Stream discharge was measured by using the following formula

$Q = wdu$ (Dunne and Leopold 1978).

where Q= is the discharge in cubic meters per second.

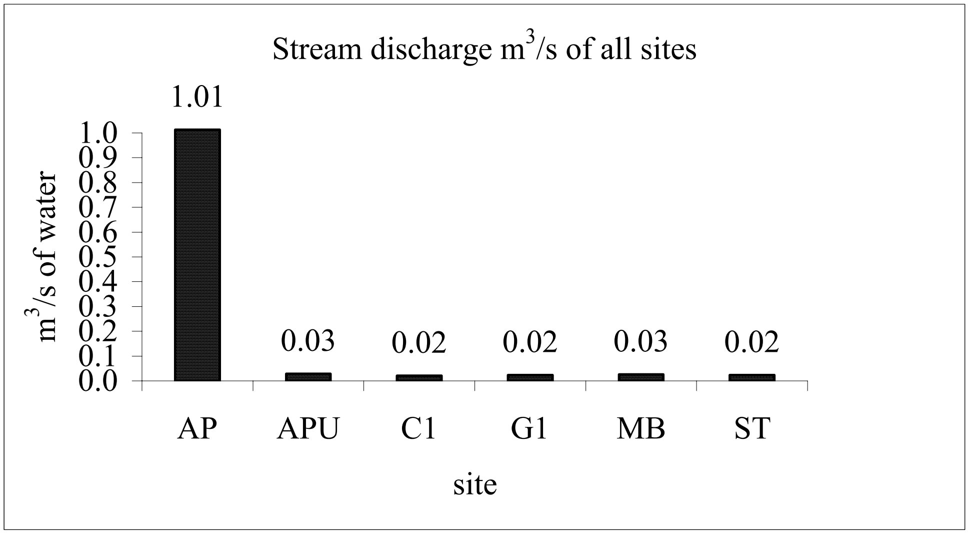
w = width in meters,

d= depth in meters

u = velocity meters/ second

At each site, ten width measurements and ten depth measurements were noted using a metric tape or ruler. To measure velocity, I measured the amount of time it took leaves to travel along the length of the stream. The ten leaves traveled down 4 meters to 10 meters and then the data were used to calculated velocity. Once these measurements were taken the data was averaged. The averages are entered in the formula to calculate volume. The average per site is found in Figure 4.14. Temperature readings for air and water were noted at each site. Appendices 3.01 and 3.02 has the raw physical data for all sites.

Figure 4.14 Stream discharge of all sites



4.05 ***Fish and Aquatic Macroinvertebrates***

There are many different methods to collect aquatic macroinvertebrates and other aquatic animals. Scientists have tested several methods for stream collection and there is no set method to collect quantitatively (Carter and Resh 2001). Animals were collected in two ways in Santa Catalina. Aquatic macroinvertebrates were gathered using a dip net with a mesh size of 800 by 900 microns. Fish were gathered in minnow traps. Both devices collected other animals as well. The aquatic macroinvertebrate analyses used two dip nets since one was stolen. In the first few runs, the larger dipnet was used six times randomly along the stream and the benthic matter was disturbed for three minutes each time. The second round of aquatic macroinvertebrate collection used a smaller dipnet. Ten random sites were selected along the stream site and the sediment was disturbed for one minute at each sampling point. The use of different tools to collect the aquatic macroinvertebrates did not affect the data. The aquatic macroinvertebrates were then sorted and identified to morphospecies. A morphospecies is an organism identified by physiological characteristics. Appendices 4.01 show the data on the aquatic macroinvertebrates from each site. Identifying organisms to species is sometimes difficult, especially with aquatic macroinvertebrates. In many studies morphospecies are used instead to answer the biological question (Allan 1973; Basset 1996; Barger *et al*. 2002;).

The lower parts of Arroyo Porâ and Arroyo Mbarakaja were deep enough to sample with minnow traps but the other stream sites were too shallow for the minnow traps. I placed minnow traps in the sites APL, APM-S in 2002 and the MB and APM sites in 2001. The MB site was not tested in the last year due to lower water levels preventing the minnow traps from working effectively. The traps were set at dusk and retrieved the following morning. No food was added to the traps to attract the fish. I did a few trial runs with food and found no difference in the type or the quantity of the fish that entered the trap.

The Shannon diversity test was calculated using data collected on the aquatic animals. Shannon-Weaver using log with any base (Zar 1999)

$$D = - \Sigma p_i \operatorname{Log} p_i$$

Where $\boldsymbol{D}$= Diversity and $\boldsymbol{p_i}$= proportion of individuals per species over total captured.

4.06 *Land-use Interviews*

After two years sampling the streams within properties, I interviewed twelve families about their properties and how they view streams, land erosion and buffer zones. The questions were asked in the following order by the help of a local schoolteacher Gloria C. Martinez-Colman using Guarani in some cases. The questions translated from Spanish, were:

1. Name of family, hectares, and crops
2. Where do you get your potable water? What happens during drought?
3. Where do you get firewood?
4. How meters away?
5. What are the major problems within your property?
6. Where does the soil go when it is eroded away?
7. Where are there streams on your property?
8. What do you use the streams for?
9. What are the uses of the land surrounded the streams?
10. How have the streams changed since you have been here in Santa Catalina?

These interviews were done within the space of one week in the last week of November 2002. This method is considered as semi-structured interviewing (Bernard 2002)

Appendix 5.01 shows the results of these surveys.

Chapter 5 Results and Discussion

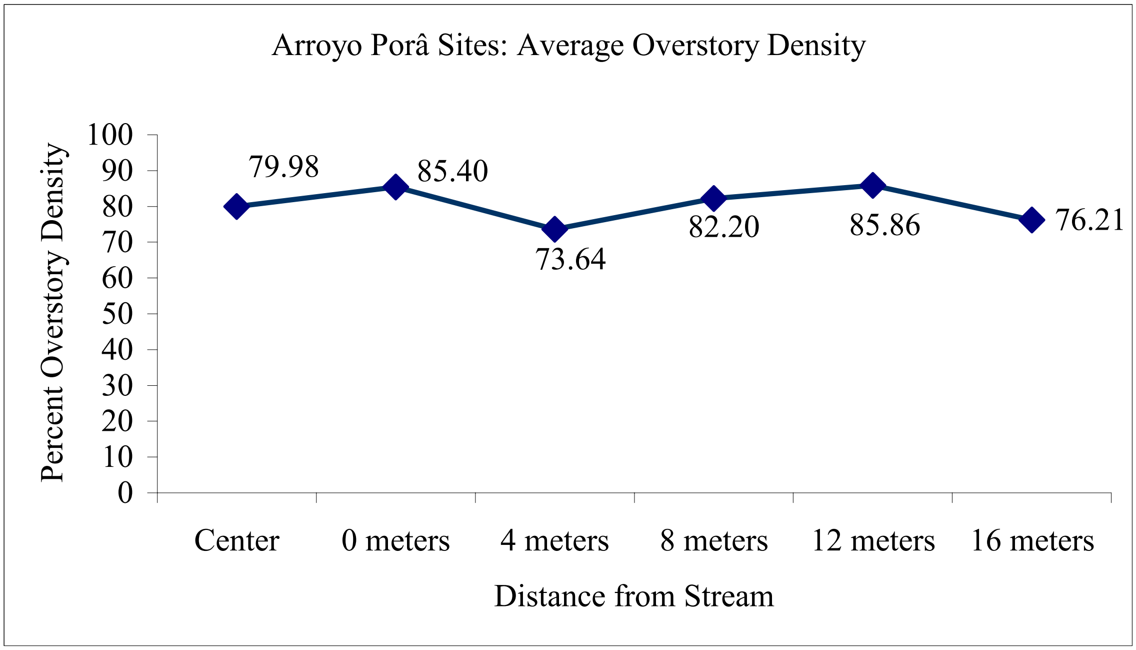
A basic understanding of the Santa Catalina watershed can help with future management plans. These data will provide for the base of further studies on specific aspects of the watershed in Santa Catalina or any other communities with extensive watersheds within the Ybytyruzu Mountain Range. I found a relationship among aquatic macroinvertebrate diversity, dissolved oxygen concentrations in the stream, and riparian overstory density. Previous studies have shown correlations among land use, aquatic insect diversity and dissolved oxygen concentrations in streams and rivers (Daly *et al.* 1998; Phillips 1989). Aquatic macroinvertebrate diversity is higher in regions of higher riparian overstory density versus riparian zones with low overstory density. Dissolved oxygen concentrations of water are lower in streams with lower overstory density versus streams with high overstory density. Secondly, I found an association between the pH of the stream water and land use along the stream near charcoal kilns.

5.01 *Lower Arroyo Porâ sites*

5.01.1 *Riparian overstory density*

The lower three sites in the Arroyo Porâ are similar to each other and therefore the data were combined and calculated as a single research site. The riparian overstory density reflects a mosaic landscape. A typical pasture in Santa Catalina has overstory density ranging between 30 percent (with few trees) to 80 percent (with larger trees and little understory density) overstory coverage. Appendix 1.01 shows the values for all transects for overstory density. The average overstory density for this site ranged between 73.7% to 85.9% overstory coverage (Figure 5.01). The rocky outcroppings along the stream prevent erosion and there is no evidence of sedimentation as noticeable as in Arroyo Mbarakaja. Most of the riparian zone is forested with openings for the movement of cattle. The riparian zones around the stream are steep and not suitable for cultivation. These attributes deterred many farmers from destroying the forests surrounding the stream.

Figure 5.01: Arroyo Porâ sites Overstory Density



Of farmers who were interviewed about their land use, a few used all arable land and others preserved the riparian zones because of the potential problems associated with deforestation of stream banks. In one example, two farmers lived side by side, about 500 meters from Arroyo Porâ. One farmer had land cultivated to about 100 meters from the stream and the other was about 50 meters from the stream. The first farmer used every piece of cultivated land to the fullest. He and his family intercropped and used contour plowing, conserving the land from excessive depletion of nutrients and severe erosion.

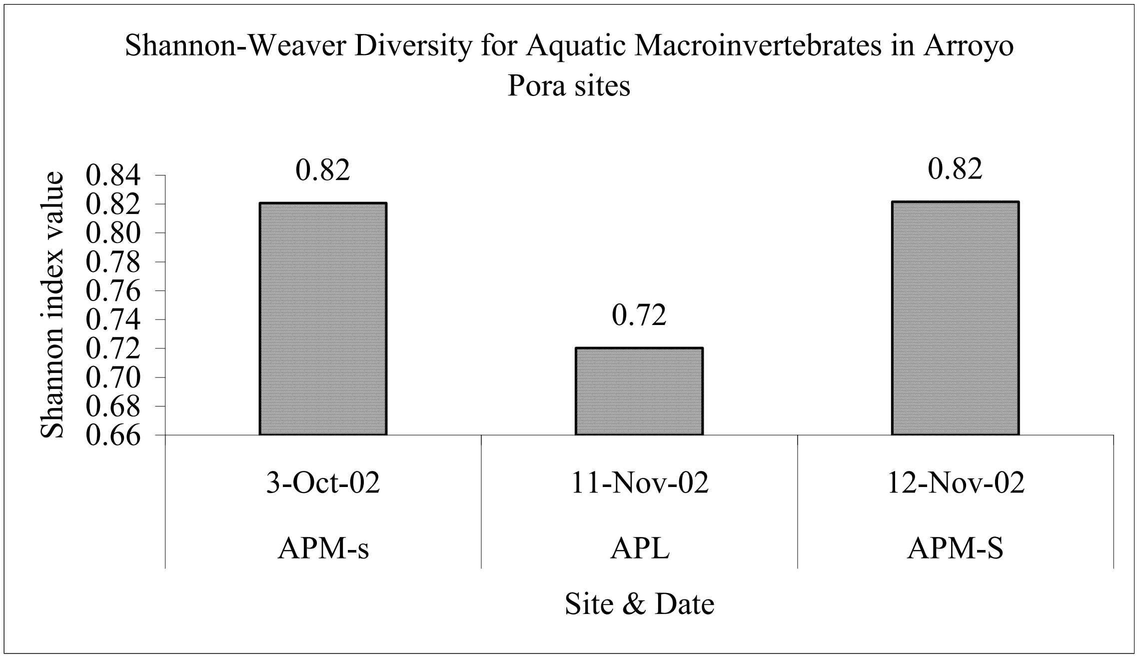
Tracts of land not used for cultivation were forested with small woodlots or lay fallow. The other farmer has more erosion problems with small gullies running throughout his pasture. The only thing preventing this landowner from cultivating up to the stream edge are the steep slopes and rocky outcroppings along the stream. The size of the family may be the major factor in how the land is used. The farmer with 100 meters of buffer zone has seven people living off the production of 20 hectares. The other family has between fifteen to twenty people in the house at one time, living off the production of 20 hectares.

5.01.2 *Aquatic macroinvertebrates and Fish*

The Arroyo Porâ sites had an abundance of aquatic macroinvertebrates and fish species. Figure 5.02 shows Shannon-Weaver diversity. These five sites had insects from the orders Coleoptera (waterpenny), Trichoptera (caddisfly) Ephemeroptera (mayfly) and Plecoptera (stonefly). These insect orders are important in detecting water quality and are used in biomonitoring (Eaton and Lenat 1991; Resh and Jackson 1993; Lydy *et al*. 2000; Morse 1980; Lenat *et al.* 1980; Zweig and Rabeni 2001).

Arroyo Porâ is large enough to sustain a wide variety of fish from the Loricariidae family, in particular the *Ancistrus spp*.; the Characidae family, in particular the *Astyanax sp.;* and the Cichlidae family with one particular species, *Crenicichla lepidota* (Agbayni 2002). Since the other streams were too small to sustain fish species other than an occasional armored catfish *Ancistrus sp*., a comparison among the streams was not done.

Figure 5.02: Diversity of aquatic macroinvertebrates of Arroyo Porâ



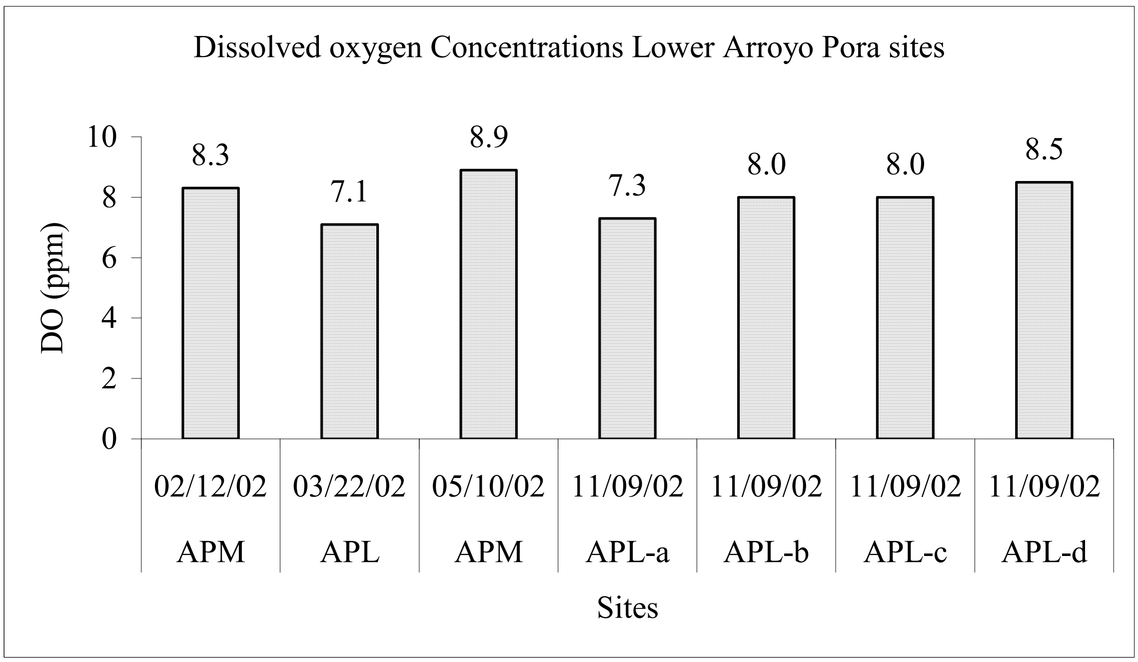
5.01.3 *Chemical Analyses*

Dissolved oxygen concentrations were found to be at safe levels at the Arroyo Porâ sites (Table 5.01 and Figure 5.03). The variations in concentrations may indicate different habitats. Variation in results indicates seasonality and sampling from different depths. Small changes in pH may indicate pollution from different sources. Charcoal kilns are present along Arroyo Porâ. Wood ash from the charcoal kilns may increase pH. I did not observe any charcoal production at the lower Arroyo Porâ sites. Charcoal production was more extensive in the past along the stream according to the local farmers. The price of charcoal is low and farmers are not producing as much as in the recent past. The pH of lower Arroyo Porâ sites is consistent throughout the year. Values of pH were consistent throughout the year ranging from 7.0-7.6 (Table 5.01).

Table 5.01: Dissolved Oxygen Concentrations and pH values for Arroyo Porâ

Site	Date	pH	Dissolved oxygen
APM	12-Feb-02	7.4	8.3
APL	22-Mar-02	7.0	7.1
APM	10-May-02	7.4	8.9
APM-S	04-Sep-02	7.6	n/a
APL-a	9-Nov-02	7.5	7.3
APL-b	9-Nov-02	7.3	8.0
APL-c	9-Nov-02	7.2	8.0
APL-d	9-Nov-02	7.1	8.5
Range		7.0-7.6	7.3-8.9

Figure 5.03: Dissolved oxygen concentrations



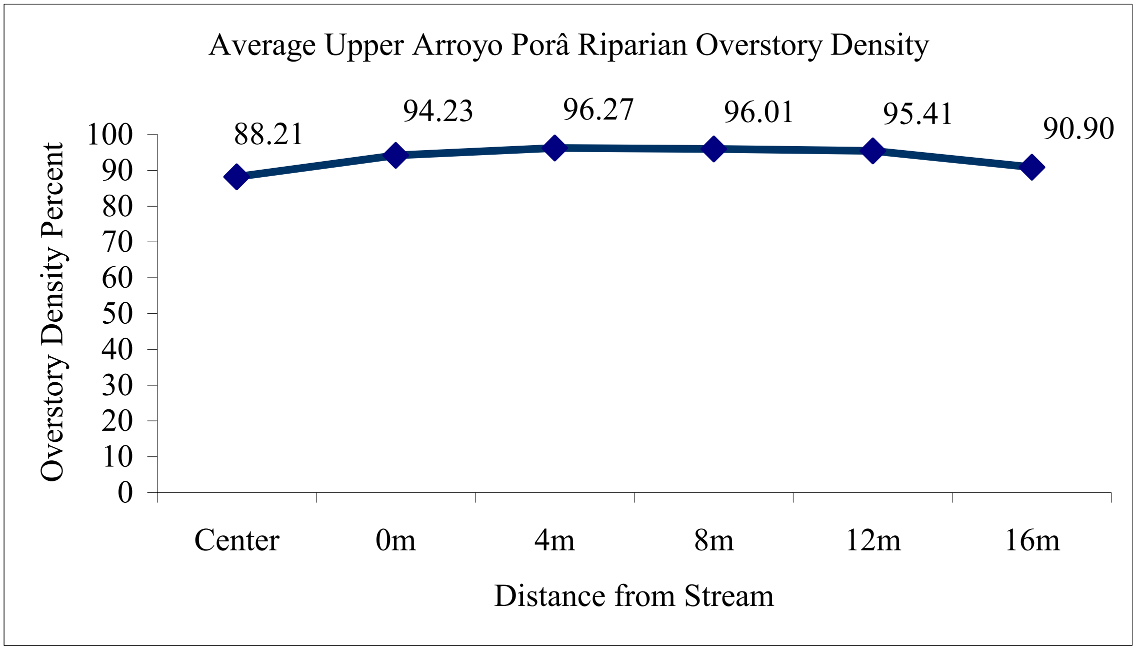
5.02 *Upper Arroyo Porâ Site*

5.02.1 *Riparian overstory density*

The upper portion of the Arroyo Porâ has little or no human influence. Overstory density was expected to be high. During my field research, I encountered some activity involving extraction of trees for use in charcoal production. A charcoal kiln is present

300 meters downstream from the study site. Dense stands of bamboo and steep slopes prevented data collection further than eight meters from the stream bank. The values of the last eight meters in some cases were estimated visually. Overstory density changes little along transects, indicating little natural and human disturbance (Figure 5.04). Natural disturbance such as a windstorm or fire occurs every five to ten years according to the residents of the Santa Catalina. During severe drought forest fires are more likely. Several years ago the mountainside of Cerro Primo Amor was burned. The mountainside has uneven canopy structure indicating a recent fire. Windstorms are more common causing gaps within the forest structure and allowing the regeneration of bamboo. Despite these occasional occurrences, upper Arroyo Porâ has the highest percent canopy coverage compared to the other study sites. The canopy cover ranges from 88 to 96 percent (Figure 5.04).

Figure 5.04: Upper Arroyo Porâ transect



5.02.2 *Aquatic Macroinvertebrates*

Upper Arroyo Porâ with its ephemeral water flow allowed only one sampling for aquatic macroinvertebrates. Upper Arroyo Porâ does not have high diversity compared to other sites and this may be because of low stream discharge and an overall small size of the stream (Table 5.02). The interesting thing about this site is the species composition seems to be different than that found in the lower Arroyo Porâ sites. Decapoda and Odonata macroinvertebrate orders were found at this site. Both species were different from the other species found in the lower portion of Arroyo Porâ. Less human influence on the landscape may be a reason for this. Only one sampling date for aquatic macroinvertebrates was possible in 2001.

Table 5.02: Upper Porâ Macroinvertebrate diversity

Site	Date	Species	Individuals	Shannon-Weaver
APU	17-Nov-01	4	7	0.55

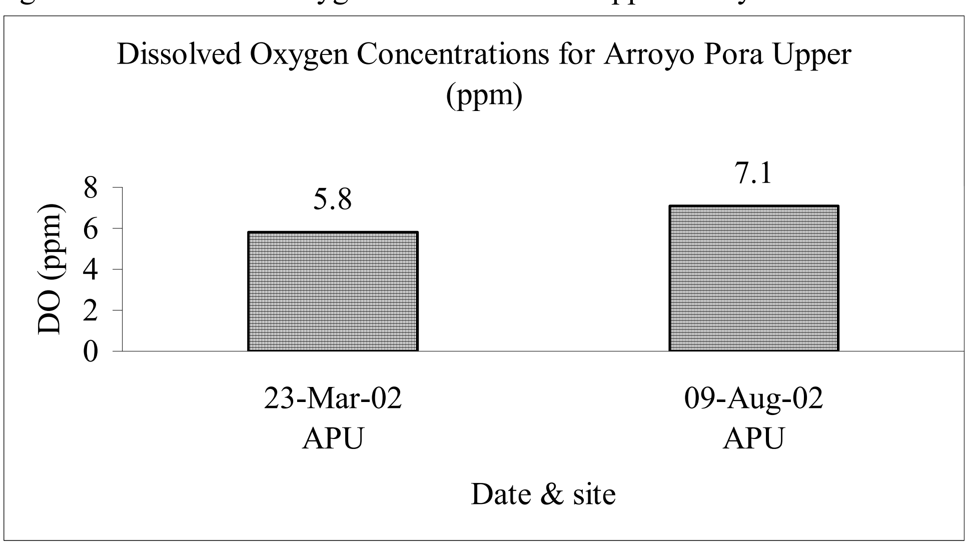
5.02.3 *Chemical and Physical Analyses*

Stream discharge was negligible in August of 2001 and March of 2002. The stream is groundwater and surface runoff dependent. During dry spells the stream has little or no water flow in some parts. The upper Arroyo Porâ site had less influence from agriculture activities and it is reflected in a steady pH level from 7.0-7.2 (Table 5.03) when compared to other small streams in the watershed. Figure 5.05 show the dissolved oxygen concentrations for the upper Arroyo Porâ stream

Table 5.03: Dissolved Oxygen concentrations and pH

Stream	Date	pH	Oxygen (ppm)
APU	23-Mar-02	7.0	5.8
APU	09-Aug-02	7.1	7.1

Figure 5.05: Dissolve Oxygen Concentrations Upper Arroyo Porâ

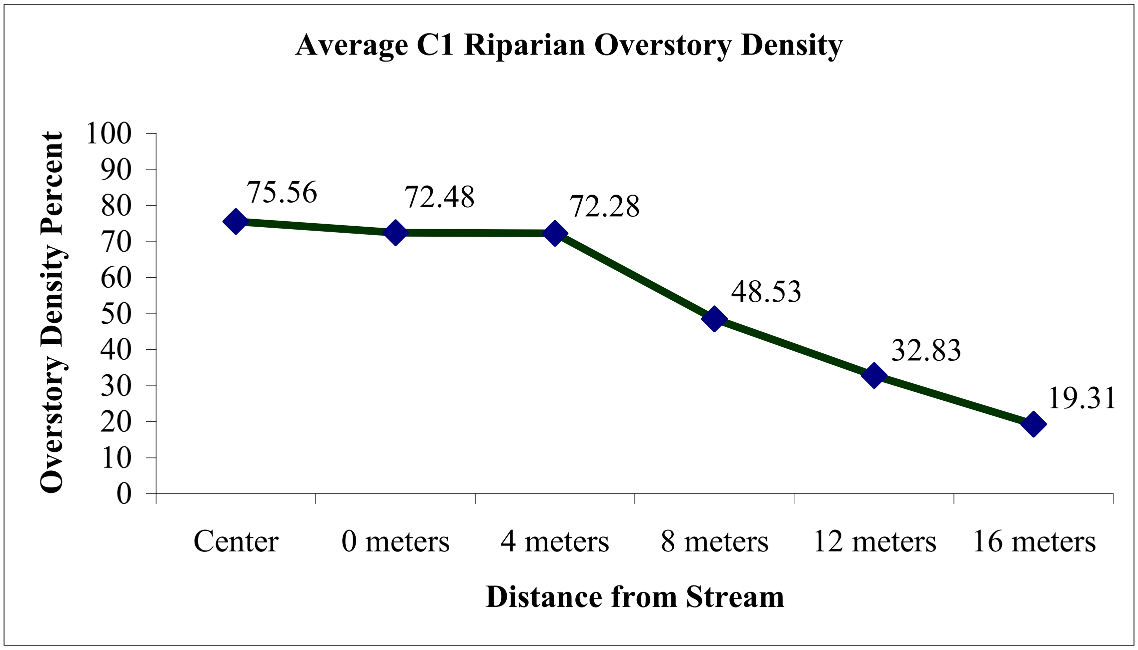


5.03 *C1 Stream Site*

5.03.1 *Riparian overstory density*

The C1 stream site overstory density is distinctly different from the other stream sites. Higher human population density and livestock are present near this stream. The C1 site is within a pasture. The stream travels into forest, combines with another small stream and passes through the ST stream site. The C1 stream site originates from a spring about 500 meters upstream from the C1 study site. The riparian zone consists of secondary forest and is degraded as it changes to pasture (Figure 5.06). The C1 site has relatively low overstory density near the stream banks when compared to other sites and decreases with increasing distance from the stream. The percent cover ranges from 19.3 percent to 75.56 percent covered. This stream (C1) is small and parts of the banks are eroding. Landowners are unconcerned or unaware for protecting riparian zones of small streams, even though they are part of an intricate network of streams.

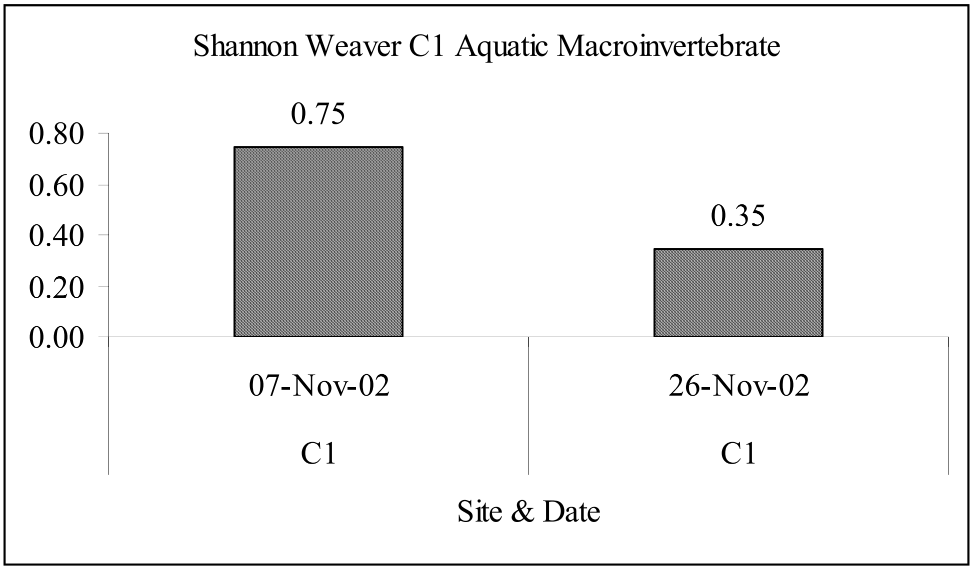
Figure 5.06: Average C1 Riparian Overstory Density



5.03.2 *C1 Aquatic Macroinvertebrate Diversity*

C1 stream insect diversity and quantity of individuals captured were relatively low compared to the other five sites. Five orders are represented in the kick net analyses. Arthopoda order included one species in the Decapoda family; Diptera with several species in the Chironomidae family, Coleoptera, Ephemeroptera, and Odonata were found at this site. Figure 5.07 shows Shannon Weaver Diversity.

Figure 5.07: Shannon Diversity Index for C1 aquatic macroinvertebrates



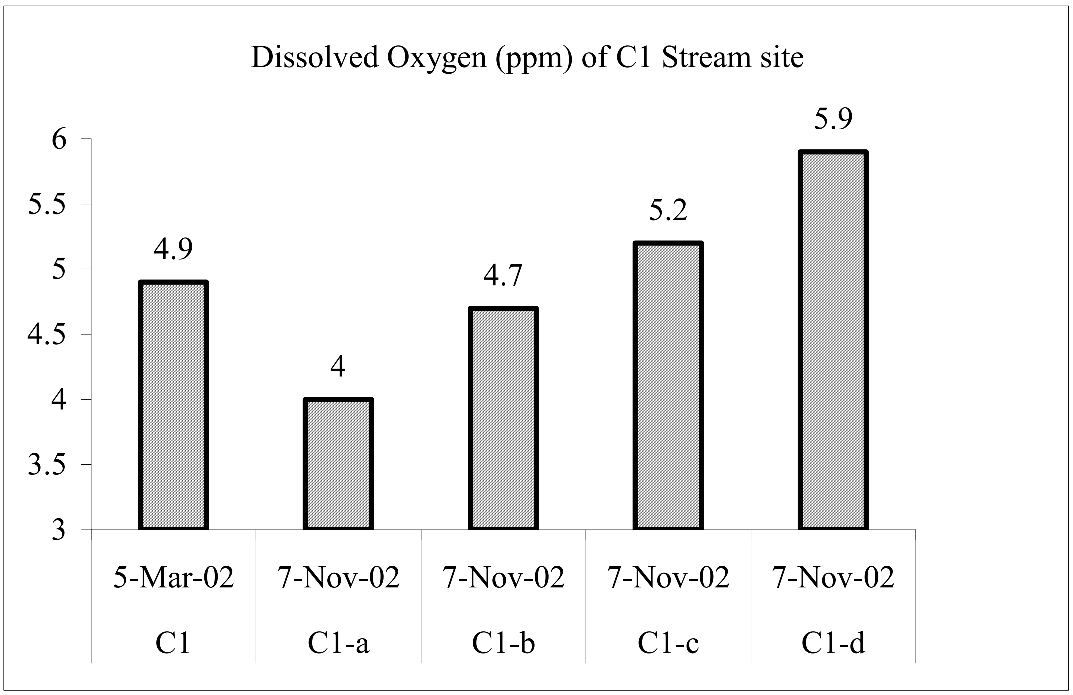
5.03.3 *Chemistry Analyses*

Because of the pasture surrounding the stream, the C1 site has differences from the other five sites in dissolved oxygen concentrations and pH levels. The dissolved oxygen concentrations for the C1 site are consistently lower than all the other stream sites. The stream pH tends to be slightly more acidic (Table 5.04 and Figure 5.08). Since the C1 site was upstream from the ST site, I expected similar pH values but they were consistently different.

Table 5.04 pH and dissolved oxygen values

Site	Date	Oxygen (ppm)	pH
C1	5-Mar-02	4.9	6.9
C1-a	7-Nov-02	4.0	6.8
C1-b	7-Nov-02	4.7	6.9
C1-c	7-Nov-02	5.2	6.8
C1-d	7-Nov-02	5.9	6.5
Range		4.0-5.9	6.5-6.9

Figure 5.08: Dissolved oxygen Concentrations for C1 stream site

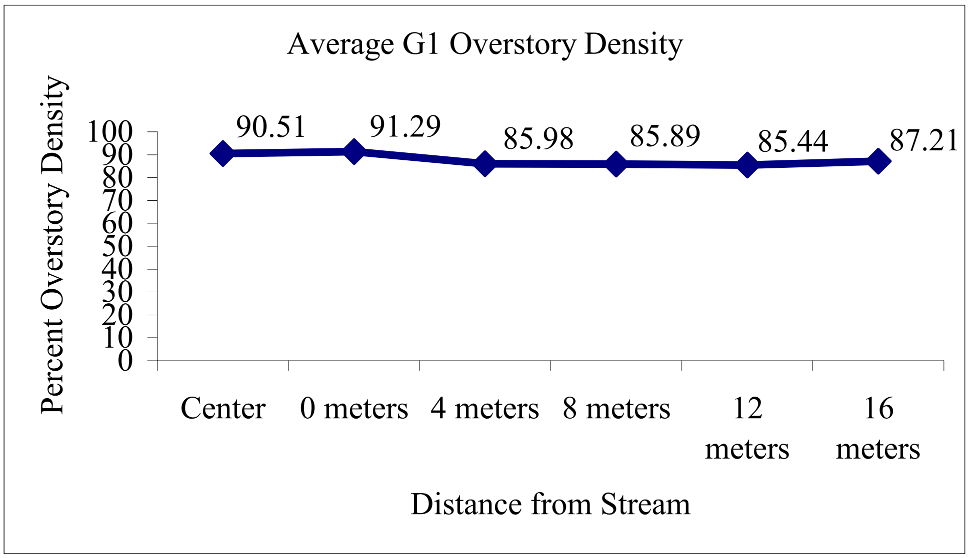


5.04 *G1 Stream Site*

5.04.1 *Riparian overstory density*

The G1 site is in a shaded pasture with few domestic animals present. This landowner left it forested along the stream to be used as a shaded pasture. Farther downstream, about 100 meters, a different landowner destroyed all the trees along the stream leaving the stream a patchwork of degraded forest and agriculture land. The owners of the G1 stream site worked on agroforestry systems with me and were aware of the problems with erosion along the stream banks. Figure 5.09 depicts the trend along transects. Overstory density ranges between 85.44 and 91.29 percent coverage. This is the highest overstory density observed among the small streams.

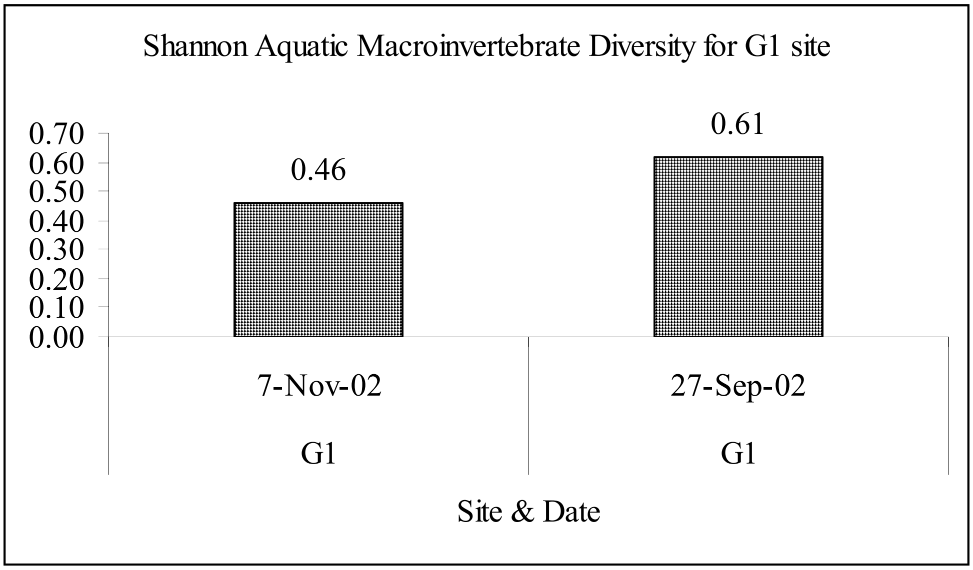
Figure 5.09: G1 Overstory density



__5.04.2__ Aquatic Macroinvertebrates

The G1 aquatic macroinvertebrate diversity is higher than the other small streams. Several important macroinvertebrate orders were found in this stream including Decapoda, Ephemeroptera, Odonata, Coleoptera and Diptera. The mayfly (Ephemeroptera) and the water penny (Coleoptera) are considered sensitive to changes in water quality (Murvosh 1971; Daly *et. al* 1998). The diversity indices for each collection date are shown in Figure 5.10. The G1 site has higher diversity than the other small streams and more individuals were found than the C1 site.

Figure 5.10: Shannon Diversity for G1 Insects



5.04.3 *Chemical Analyses*

The pH and dissolved oxygen concentrations are at safe levels for aquatic animals at the G1 site. Variations in dissolved oxygen concentrations are due to seasonal fluctuations. Table 5.05, Figure 5.11 and Figure 5.12 display dissolved oxygen concentrations and for the G1 site.

Table 5.05 G1 site dissolved oxygen concentrations and pH values

Site	Date	pH	Dissolved Oxygen
G1	1/28/2002	7.2	7.05
G1	5/6/2002	7.3	8.05
G1-a	7/13/2002	7.6	n/a
G1-b	7/13/2002	7.4	n/a
G1-c	7/13/2002	7.2	n/a
G1-d	7/13/2002	7.1	n/a
G1-e	7/13/2002	6.9	n/a
G1-f	7/13/2002	7.3	n/a
G1-g	7/13/2002	7.3	n/a
G1	9/17/2002	7.4	6.6
G1-1	11/7/2002	7.0	6.2
G1-2	11/7/2002	7.4	6.4
G1-3	11/7/2002	7.1	6.8
G1-4	11/7/2002	7.3	5.4

Figure 5.11: Dissolved oxygen concentrations

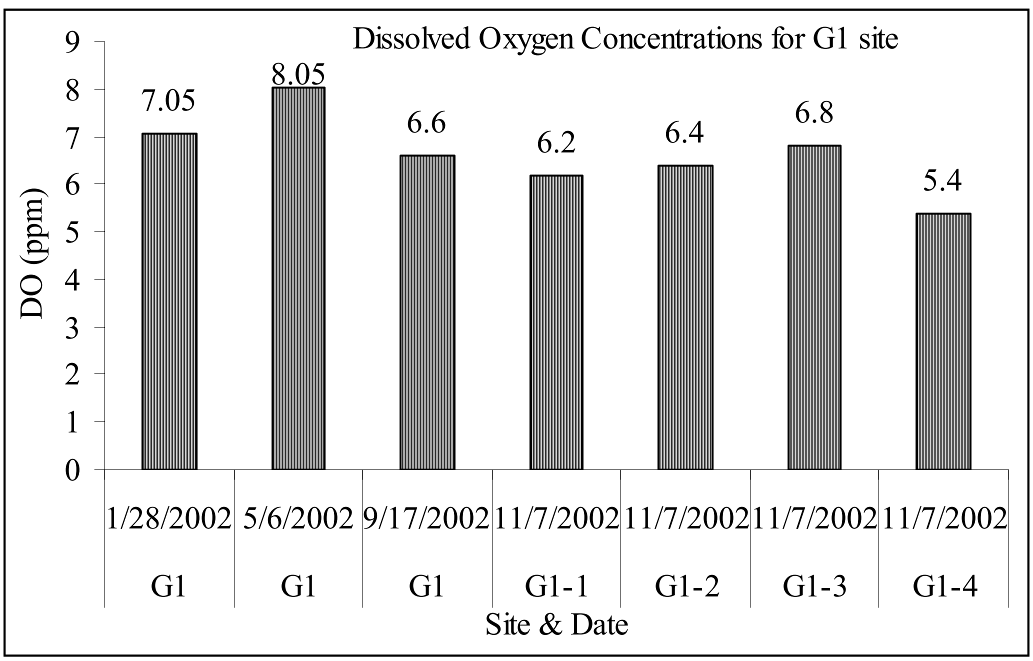
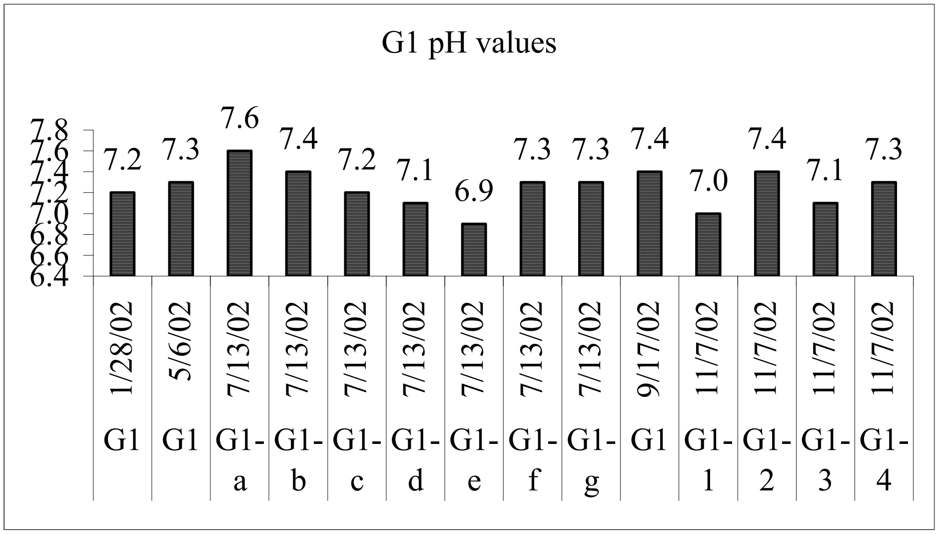


Figure 5.12: G1 pH values

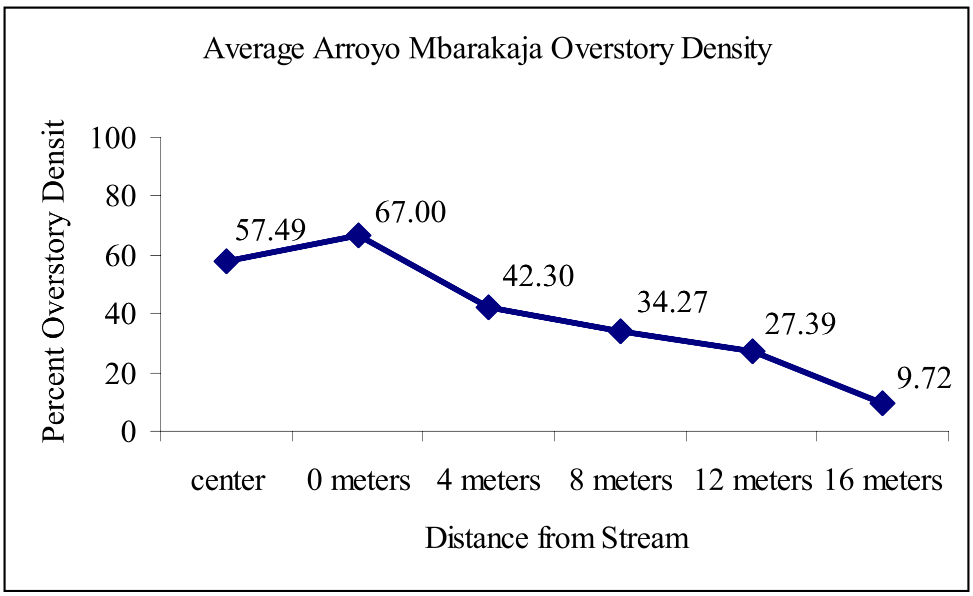


5.05 *Arroyo Mbarakaja*

5.05.1 *Riparian overstory density*

Arroyo Mbarakaja site is in a heavily grazed pastureland. The soil is sandy and easily eroded. The riparian zone has a few trees, allowing the cattle to cross the stream to look for better grass to eat. Figure 5.13 shows the values of the overstory density. The percent overstory canopy ranges between 9.72 to 67.00 percent. The soil type is different compared to the other sites in this study. Sandy soils lead to more erosion and trampling by the cattle causes deterioration of the stream banks.

Figure 5.13: Overstory Density Arroyo Mbarakaja



5.05.2 *Aquatic Macroinvertebrates*

The Arroyo Mbarakaja site is similar to the C1 site with the pasture surrounding the stream. There seemed to be higher amounts of arthropods and beetles present, perhaps due to the sandy soil. There are several orders of insects present along with more arthropods present than at the other sites. Odonata, Trichoptera, Decapoda and Coleoptera are the common orders. Table 5.06 shows data on the number of species and the number of individuals sampled along with the diversity indices.

Table 5.06: Shannon diversity for Arroyo Mbarakaja

Site	**Date**	**Shannon-Weaver**
MB	10-Dec-02	0.68

5.05.3 *Chemical Analyses*

Arroyo Mbarakaja site showed fluctuation in the dissolved oxygen and pH values. Sour orange trees lined the stream banks upstream from my study site. The fruit littered the streams at times and this could have resulted in slightly more acidic pH readings. The February 13 sampling shows a slightly more basic pH value. The stream discharge was very low on that date and there were no sour oranges present in the stream. Table 5.07, Figure 5.14, and Figure 5.15 shows the values for the site. Dissolved oxygen concentrations fluctuated over the time period but never dangerously low for aquatic life.

Table 5.07: Arroyo Mbarakaja Chemical Analyses

Stream/site	Date	Oxygen (ppm)	pH
MB	13-Feb-02	8.2	7.5
MB	5-Jun-02	7.2	7.1
MB	22-Oct-02	7.1	6.9
MB-1	4-Nov-02	5.9	6.9
MB-2	4-Nov-02	5.3	6.9
MB-3	4-Nov-02	n/a	7.1
Range		5.3-8.2	6.9-7.5

Figure 5.14: Dissolved oxygen concentrations for Arroyo Mbarakaja

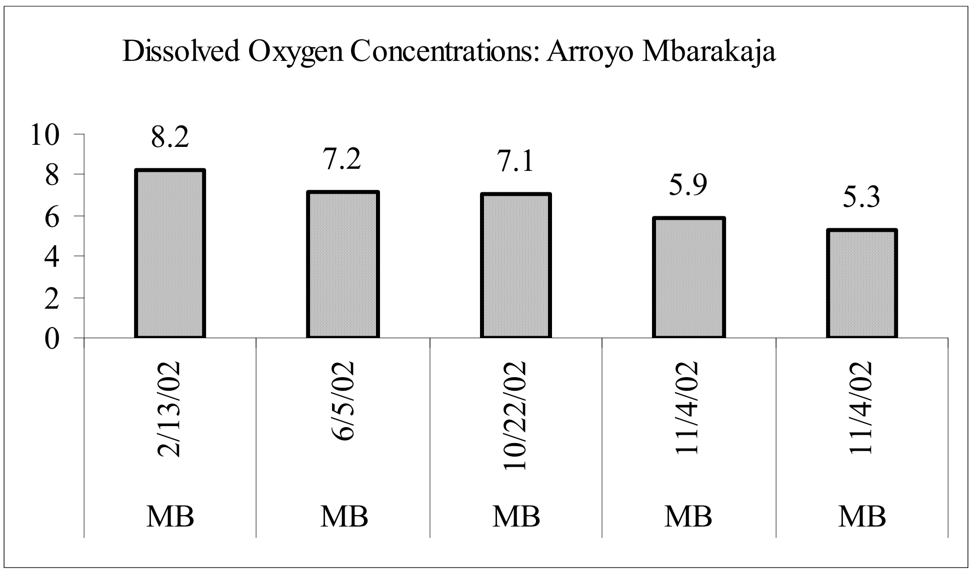
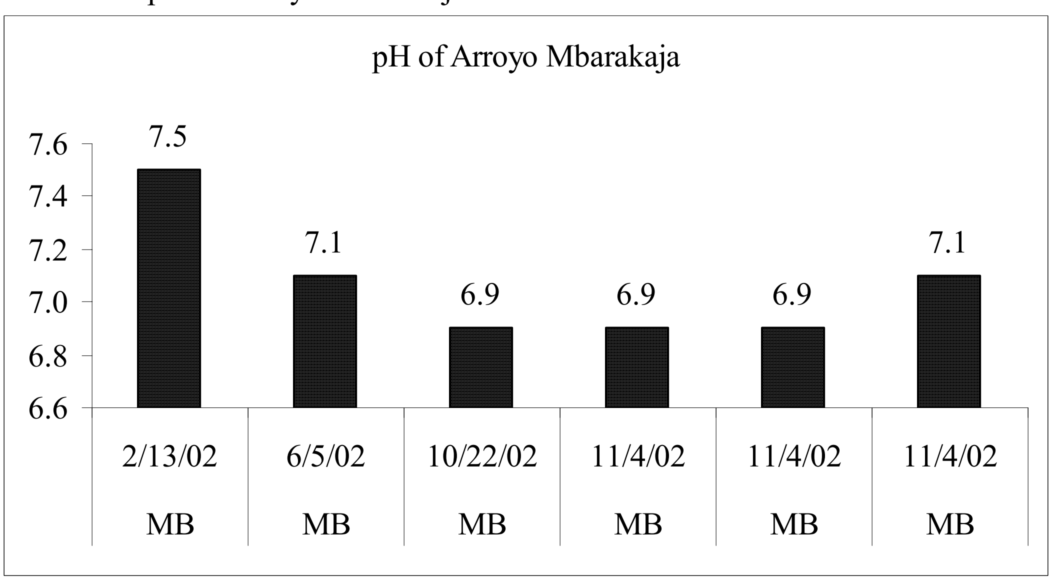


Table 5.15: pH of Arroyo Mbarakaja



5.06 *ST Stream site*

5.06.1 *Riparian overstory*

The ST stream site is about 500 meters downstream from the Cazal site. The stream is wider here because of inflow from groundwater, surface runoff and other small streams. The riparian zone between the C1 site and the ST site is forested. Fifteen transects were done. These results show a mixture of the pasture and forested parts of the riparian zone. Gathering data was difficult because of the sheer rock walls along parts of the stream banks. Along with other dense vegetation, it was difficult to enter the forest from the stream banks. The average canopy coverage ranges between 43.96 to 65.52 percent. Figure 5.16 shows the average overstory density. These figures do not reflect the high variability in overstory density. At this site there were transects of low overstory density and transects with high overstory density. Figure 5.17 shows transects with high overstory density.

Figure 5.16: Average overstory density.

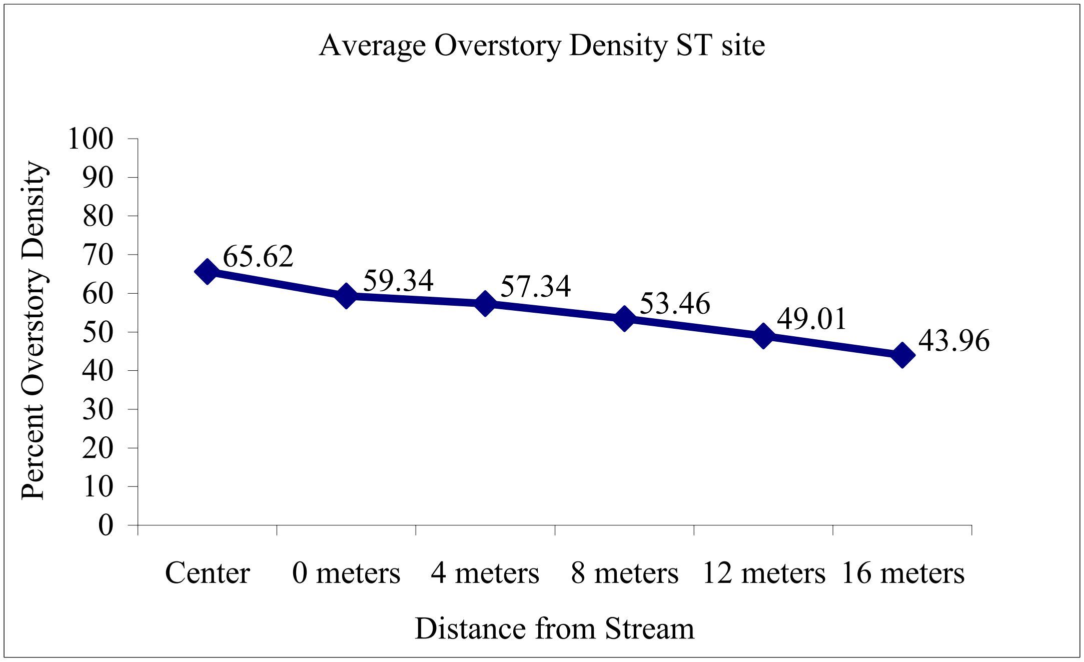
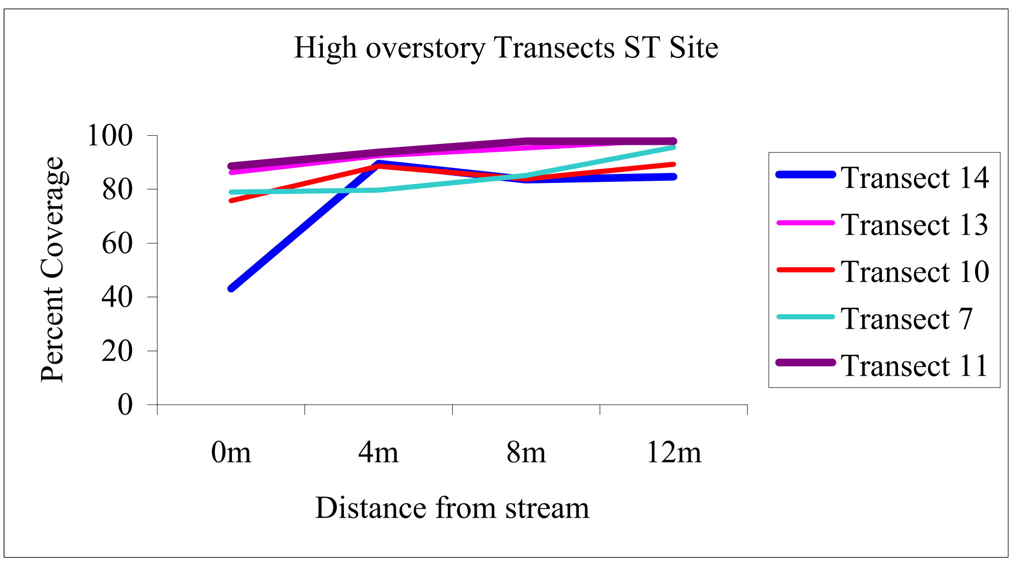


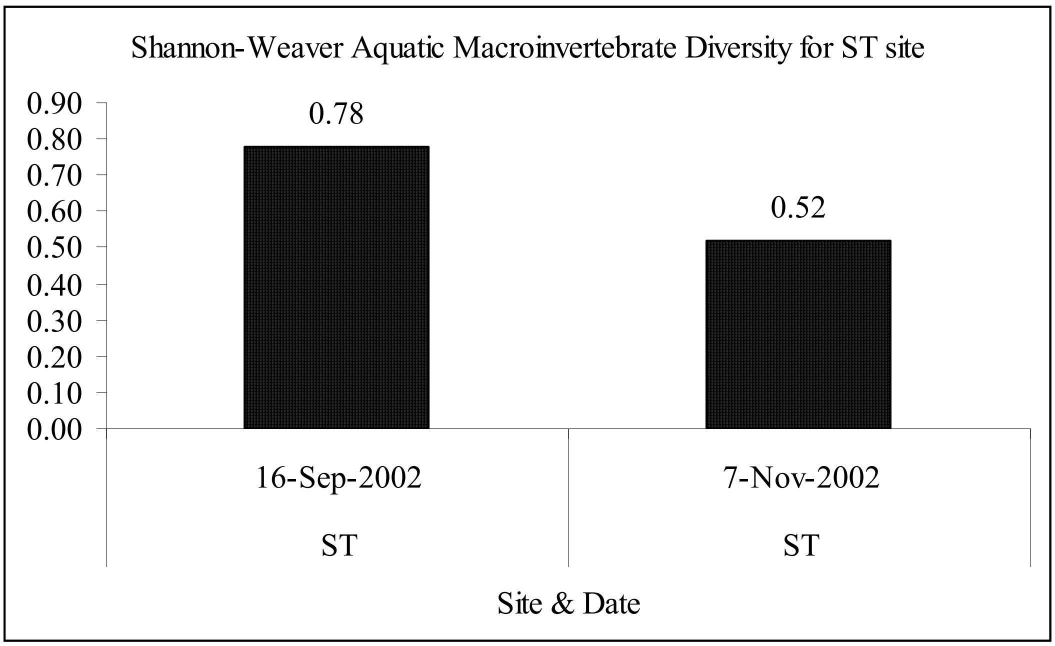
Figure 5.17: High Density Transects along Soto Site



5.06.2 *Aquatic Macroinvertebrates*

The aquatic macroinvertebrates found at this site are similar in composition as the other stream sites. Decapoda, Ephermeroptera, Coleoptera, Diptera, Odonata, and Trichoptera are several important macroinvertebrate orders found in this stream. The diversity increases in early spring when the stream has better conditions for aquatic insect larvae. Perhaps due to the heat some aquatic insects hatch earlier in greater abundance and then the insects numbers decrease in the summer. Spring 2002 (September to November) was warmer than usual and the insects seem to have come out earlier this year. Figure 5.18 shows the diversity using a Shannon index.

Figure 5.18: Aquatic macroinvertebrate diversity of the ST site



5.06.3 *Chemical Analyses*

Chemical analyses of this site did not show any unsafe levels for aquatic life. Dissolved oxygen concentrations were higher than the four parts per million (ppm) required for the aquatic life (Renn 1970). Wood ash inputs from two charcoal kilns along this stream raised the pH during the winter months. Wood ash has a pH of 9.9 to 13.9 and inputs in the water can raise the pH slightly (Whytemare 2002). During the winter the charcoal kilns are used on a regular basis. Table 5.08 and Figure 5.19 show the values for dissolved oxygen. Table 5.09 and Figure 5.20 show the values of pH. The figure depicts higher pH in the winter months with downward trend in the summer. The charcoal kiln near this site was used about three times between June and August 2001. The excess wood ash was thrown down slope toward the stream. Figure 5.21 is a photograph taken in July of 2002; the wood ash was thrown down this slope. Surface runoff washed the wood ash into the stream.

Table 5.08: Dissolved oxygen concentrations

Site	Date	Dissolved oxygen (ppm)
ST	29-Jan-02	8.6
ST	9-May-02	7.1
ST	16-Sep-02	6.1
ST	17-Oct-02	7.0
ST	7-Nov-02	6.5
ST	7-Nov-02	6.4
ST	7-Nov-02	6.5

Figure 5.19: Dissolved oxygen for the ST stream site

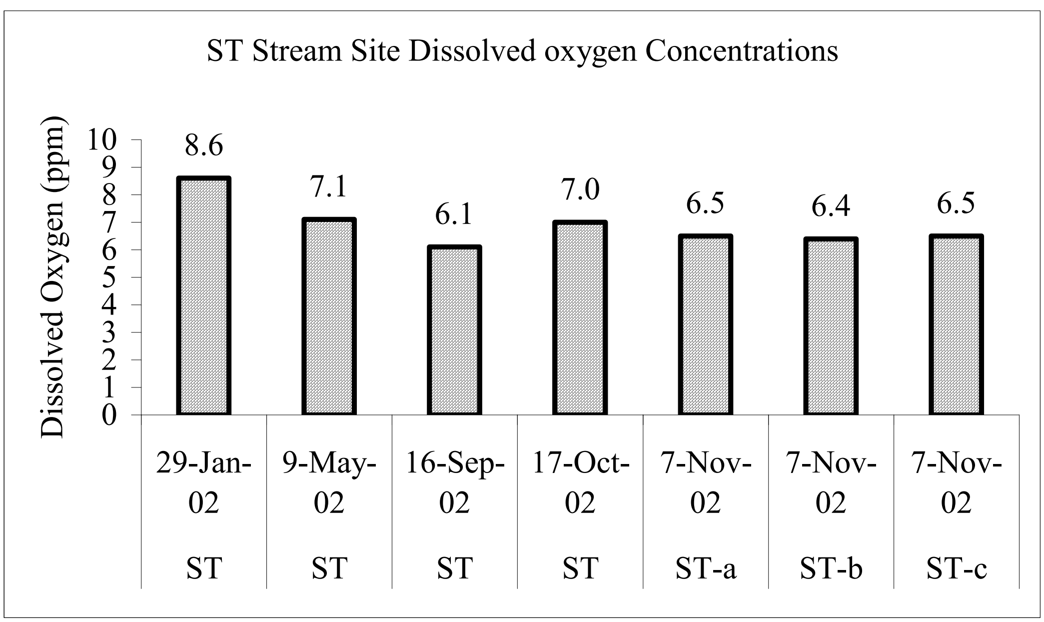


Table 5.09: pH values for ST stream site

Site	Date	pH
ST	29-Jan-02	7.1
ST	9-May-02	7.4
ST-1	13-Jul-02	7.7
ST-2	13-Jul-02	7.6
ST-3	13-Jul-02	7.8
ST-4	13-Jul-02	7.8
ST-5	13-Jul-02	7.8
ST-6	13-Jul-02	7.8
ST	16-Sep-02	7.6
ST	17-Oct-02	7.7
ST-a	7-Nov-02	7.4
ST-b	7-Nov-02	7.6
ST-c	7-Nov-02	7.6

Figure 5.20: pH ST site

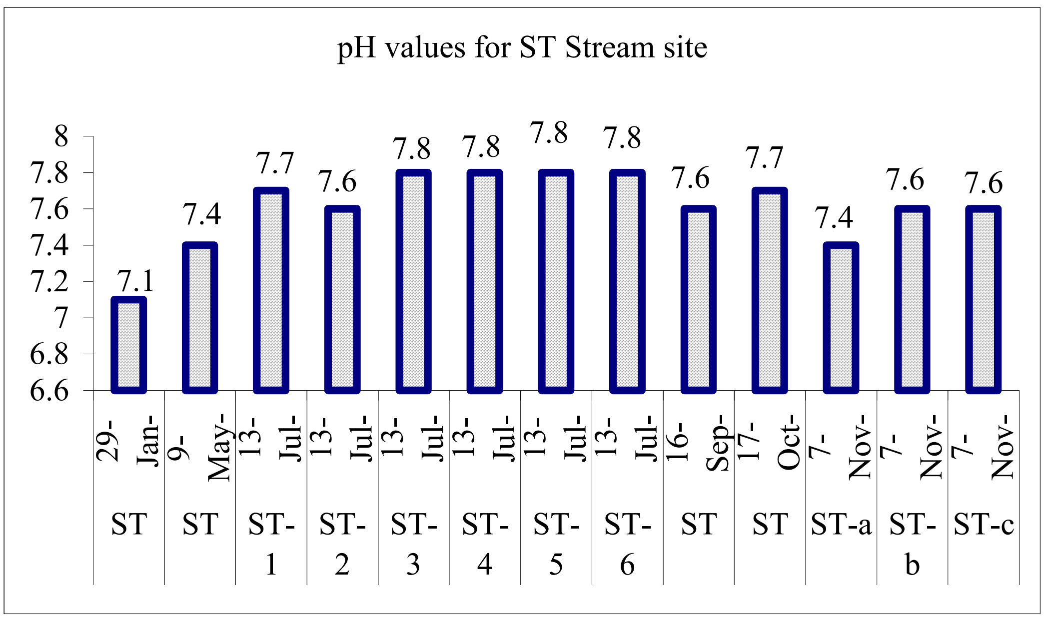


Figure 5.21: ST site stream bank

Photograph is of the stream bank at the ST site with the charcoal kiln in the upper center of the photograph.

5.07 *Land use surveys*

Riparian and stream water quality can change through anthropological disturbances (Beasley *et al.* 1984). Land use surveys are needed to understand the reasoning behind agriculture practices. The farmers of Santa Catalina like many other farmers all over the world generally do not purposely pollute streams and rivers. Decisions are based on the economic situation of each family. These farmers need to be made aware of the problems and solutions, which will not hurt their economic situation. Using anthropological surveys such as an informal questionnaire, certain information can be gathered about the land use practices of the community.

I interviewed twelve families who live and work in Santa Catalina about their land use practices. Of the families surveyed four families settled in Santa Catalina 20 to 40 years ago and each of them have noted changes in the landscape. One noticeable change is the distance each family needs to travel to gather firewood. Some families retrieve firewood from as close as 20 meters to their houses and others as far as 500 meters. The families who had the means to retrieve firewood from woodlots farther away seemed to have better quality wood versus the families who gathered near their house. Looking at the Santa Catalina landscape, the forests that remain are degraded from the collection of firewood and charcoal. Residents of the nearby village of Santa Cecilia have no woodlots left, thus traveling five kilometers to their property in Santa Catalina to retrieve firewood. Many residents of Santa Catalina want to rely on gas stoves only, but the price of gas has risen to the point where few can afford it. Consequently, families revert to the use of firewood.

Four men surveyed have worked with a Peace Corps volunteer to solve these problems on their property. These four men stated that erosion is the foremost problem on their properties. All four have sandy soils on their property and heavy rainfall results in gully formation, inducing sedimentation of the nearby streams. All families interviewed have hilly terrain on their property and some agriculture practices contribute to the erosion problems.

Several families indicated they have no problems with their land. Since Santa Catalina has few problems relative to other parts of the country some farmers do not realize the trends toward increasing erosion and decreasing fertility. Two men, before working with a Peace Corps volunteer, noticed decreasing fertility and cleared more land to plant corn or cassava. At least one cleared to the bank of a small stream. That land decreased in fertility after one year. After working with a Peace Corps Volunteer these farmers changed their agriculture practices slightly to prevent erosion by intercropping green manure or beginning a management plan to plant trees in the riparian zone of the small streams.

Many farmers see problems and when shown sound management practices are willing to adopt them. These farmers do not purposely clear land to cause low water quality of streams, they clear land to improve their family's short-term economic situation. Most farmers are willing to listen to advice on land management and they understand many concepts in natural resources. Scientific studies can provide the information to these farmers to make the improvements to their land.

5.08 *General Comparisons*

Poor land use along stream banks can allow non-point source pollution to enter the stream and a vegetated riparian buffer zone can effectively slow the process of pollutants reaching the stream (Phillips 1989). In comparing components of this study among the stream sites, several trends support previous research on streams and riparian buffer zones. My research shows relationships between overstory coverage and aquatic macroinvertebrate diversity, stream discharge and aquatic macroinvertebrate diversity, aquatic macroinvertebrate diversity and dissolved oxygen concentration, aquatic macroinvertebrate diversity and pH; EPT versus Chironomidae, and an interesting relationship between dissolved oxygen and pH.

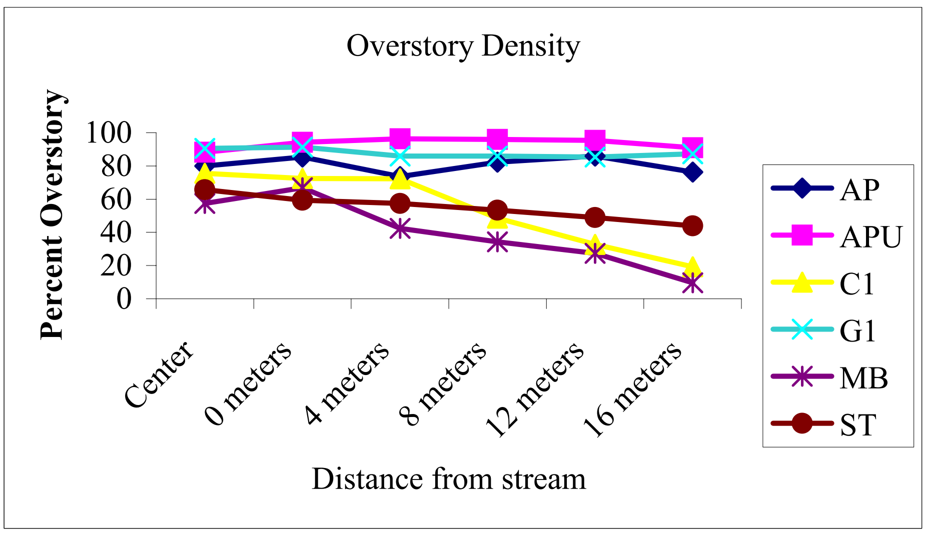
5.08.1 *Overstory Density vs. Aquatic macroinvertebrate Diversity*

Overstory density of a riparian zone depends upon whether the landowner uses the land for agriculture, pasture, or leaves it forested. Along Arroyo Porâ, some landowners clear forest for pastureland and charcoal production. The three sites ST, C1, and G1 vary in overstory density even though they are part of the same system of streams that flow into Arroyo Porâ. The structure of the riparian zone along Arroyo Porâ is not conducive for cultivation and therefore some landowners are deterred from using the riparian zones for traditional farming. For instance one landowner clears forest in the riparian zone and the other does not, creating a mosaic landscape along these tiny streams. Deforestation along the banks of these streams may cause more visible problems depending on soil type. Arroyo Mbarakaja has a sandy soil surrounding the stream. This soil type is easily eroded and deforestation can cause problems of excessive sedimentation in the stream. Arroyo Mbarakaja has visibly more erosion problems than the other sites. Table 5.10 and Figure 5.22 show overstory density for all sites.

Table 5.10: Average Percent Overstory Density for all sites.

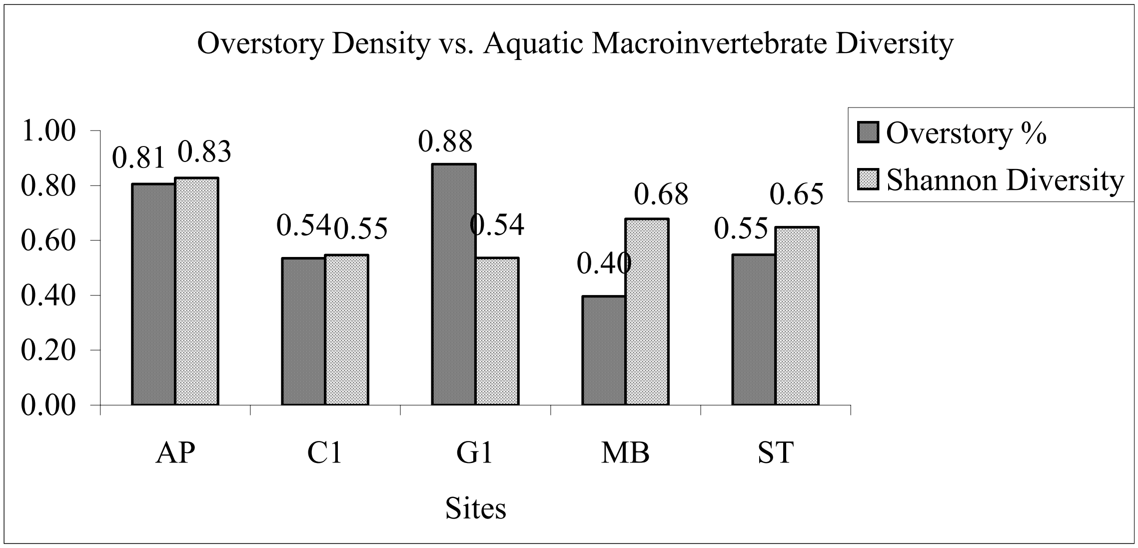
Site	**Center**	**0 meters**	**4 meters**	**8 meters**	**12 meters**	**16 meters**
AP	79.98	85.40	73.64	82.20	85.86	76.21
APU	88.21	94.23	96.27	96.01	95.41	90.90
C1	75.56	72.48	72.28	48.53	32.83	19.31
G1	90.51	91.29	85.98	85.90	85.44	87.22
MB	57.49	66.92	42.30	34.27	27.39	9.72
ST	65.62	59.34	57.34	53.46	49.01	43.96

Figure 5.22: Average Overstory Density of all sites



Land use is associated with macroinvertebrate richness, abundance levels of EPT, and tolerant macroinvertebrates (Hall *et. al* 2001). Measuring overstory density is one way to determine this relationship. Shade is important in maintaining water temperatures (Anonymous June 2002). Water temperature is correlated with dissolved oxygen concentrations. The higher the water temperature, the lower the dissolved oxygen concentrations one may find (Renn 1970). Figure 5.23 shows the Shannon index diversity versus overstory coverage.

Figure 5.23: Overstory density vs. Aquatic macroinvertebrate diversity



With exception of the APU site the other streams show a trend toward high diversity in high overstory coverage, showing the importance of riparian buffer zones supported by previous studies (Hall *et al.* 2001).

5.08.2 *Aquatic macroinvertebrate Diversity vs. Stream discharge*

Previous studies have found physical stability of a stream is related to biological stability. Aquatic macroinvertebrates are associated with different types of substrate, and substrates are related to stream velocity (Wallace 1988; Dunn and Leopold 1978). Smaller streams are less stable. Figure 5.24 shows two of the sites showing great differences in storm flow and base flow. This shows that on average small streams in the Ybytyruzu Mountain Range are not physically stable.

Figure 5.25 shows the stream discharge versus aquatic macroinvertebrate diversity. Storm flow from the G1 and ST sites is not found in the calculations of Figure 5.25 since the other streams were not measured during a storm.

Figure 5.24: Base flow versus storm flow for the G1 and ST sites

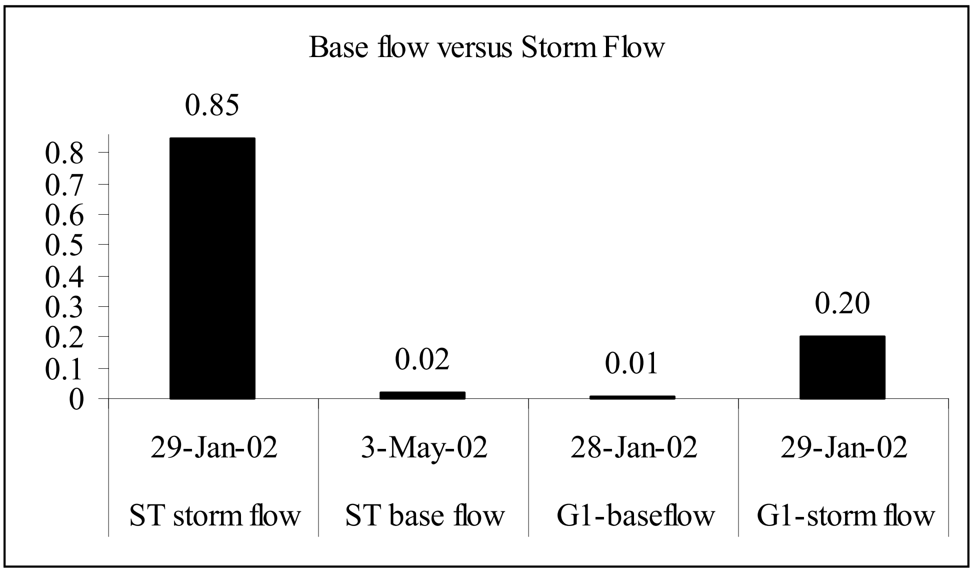
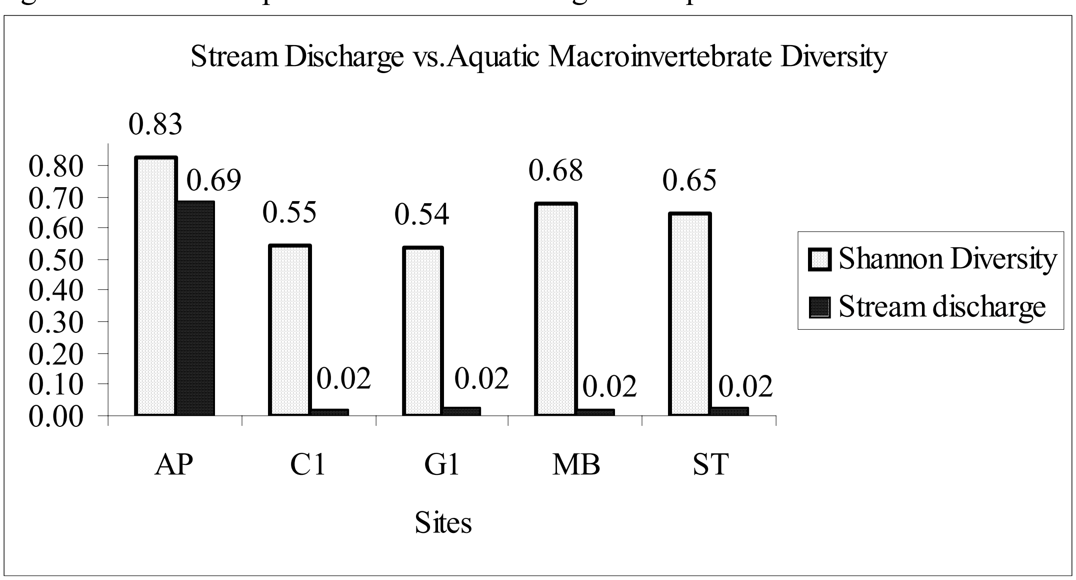


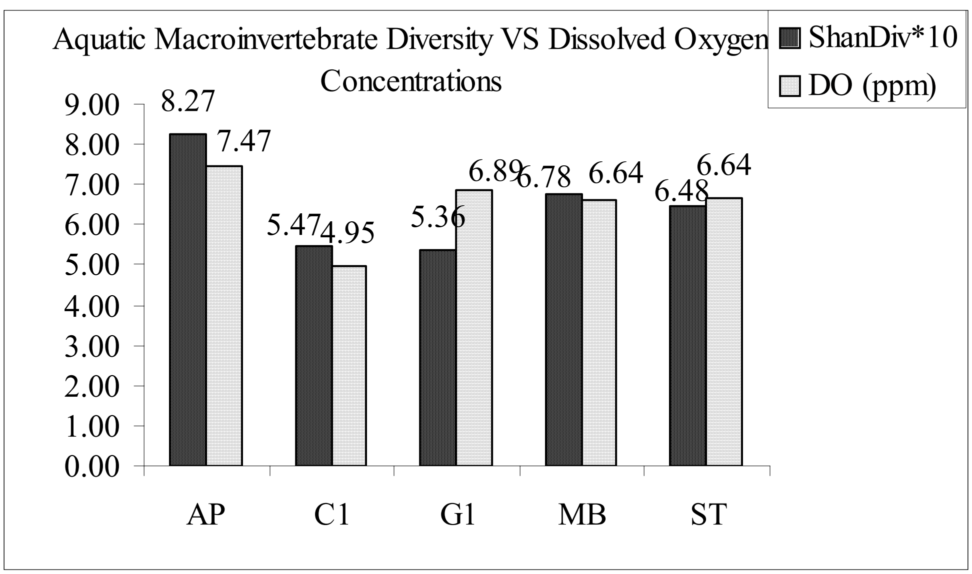
Figure 5.25 Site comparisons: stream discharge vs. Aquatic macroinvertebrate diversity



5.08.3 *EPT vs. Chironomidae and water quality sensitivity*

Low oxygen concentrations of 4.0 ppm or less may not allow certain aquatic invertebrates to survive (Renn 1970; Daly *et al.* 1998). The physiological manner aquatic macroinvertebrate nymphs take in oxygen is the reason for different levels of sensitivities (Daly *et al.* 1998). With this information, it can be assumed higher aquatic macroinvertebrate diversity will correlate with healthy oxygen concentrations. Comparing aquatic macroinvertebrate diversity versus dissolved oxygen concentrations, there is a relationship also found in Daly *et al.* (1998). Figure 5.26 shows aquatic macroinvertebrate diversity versus dissolved oxygen concentrations. Arroyo Porâ shows the relationship between the two components.

Figure 5.26: Aquatic macroinvertebrate diversity vs. dissolved oxygen concentrations



Diversity indices can describe the community composition to some extent but it may not tell the whole story. These values do not describe the type of species found at each stream. Species composition is important since some species are sensitive to changes in dissolved oxygen concentrations, pH, or temperature. The aquatic macroinvertebrate orders Trichoptera, Ephemeroptera, and Plecoptera are aquatic macroinvertebrate orders known for the sensitivity to dissolved oxygen concentrations (Lenat *et al.* 1980). The Psephenidae family (water penny) is an indicator of water quality (Murvosh 1971). Water pennies were found only at the ST, G1, and Arroyo Porâ sites. All sites had species from either the Ephemeroptera or Trichoptera. Only the Arroyo Pora had Plecoptera. The mayflies (Ephemeroptera) were abundant in all sites except Arroyo Mbarakaja. Caddisflies were most abundant in Arroyo Porâ and are present at all sites. Certain families in the aquatic macroinvertebrate order Diptera can tolerate poor water quality because they have gills (Daly *et al.* 1998). Research has shown an imbalance in species composition may indicate poorer conditions. Greater abundance of Chironomidae family versus the EPT orders indicates an imbalance in the species composition (Resh and Jackson 1993). The C1 site is the only site with more individuals in the Chironomidae family than the sensitive aquatic macroinvertebrate orders. Arroyo Mbarakaja has few of the sensitive species and with its sandy benthic composition, it may be more suitable for different types of organisms such as the Decapoda family. Data shows more macroinvertebrates present at the Arroyo Mbarakaja site, primarily freshwater shrimp and crabs. Table 5.11 and Figure 5.27 show the aquatic macroinvertebrate diversities for all of the sites. Table 5.12 and Figure 5.28 show comparisons among aquatic macroinvertebrate orders or families at each site.

Table 5.11: Diversity of all sites, ranked by Shannon-Weaver Index

Site	Date	Shannon-Weaver
C1	11/26/02	0.35
G1	11/07/02	0.46
ST	11/07/02	0.52
G1	09/27/02	0.61
MB	12/10/02	0.68
AP	11/12/02	0.69
C1	11/07/02	0.75
ST	09/16/02	0.78
AP	11/11/02	0.82
AP	10/03/02	0.97

Figure 5.27: Aquatic macroinvertebrate diversity for all sites

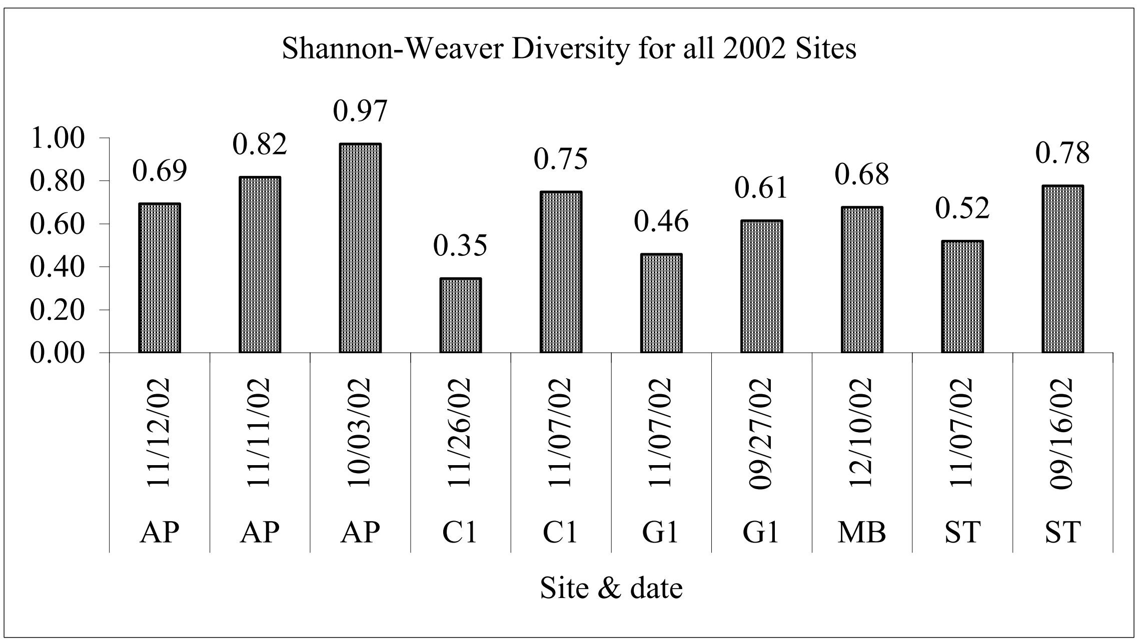
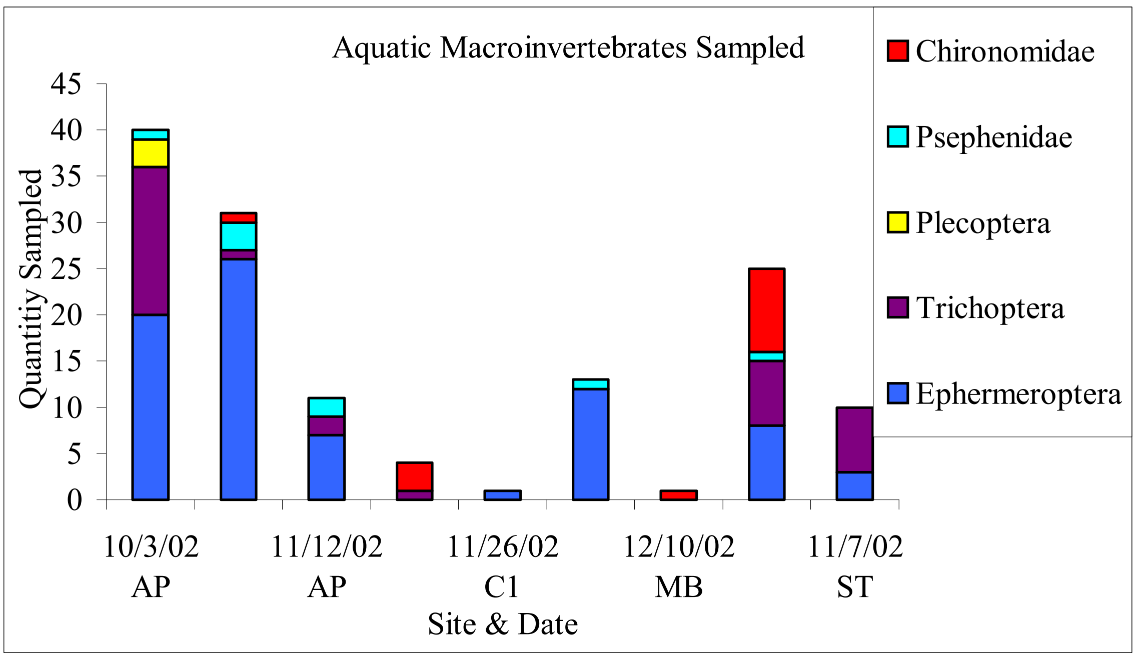


Table 5.12 Aquatic macroinvertebrate taxa

Site	Date	Ephermeroptera	Trichoptera	Plecoptera	Psephenidae	Chironomidae
AP	10/3/2002	20	16	3	1	0
AP	11/11/2002	26	1	0	3	1
AP	11/12/2002	7	2	0	2	0
C1	11/7/2002	0	1	0	0	3
C1	11/26/2002	1	0	0	0	0
G1	9/27/2002	12	0	0	1	0
MB	12/10/2002	0	0	0	0	1
ST	9/16/2002	8	7	0	1	9
ST	11/7/2002	3	7	0	0	0

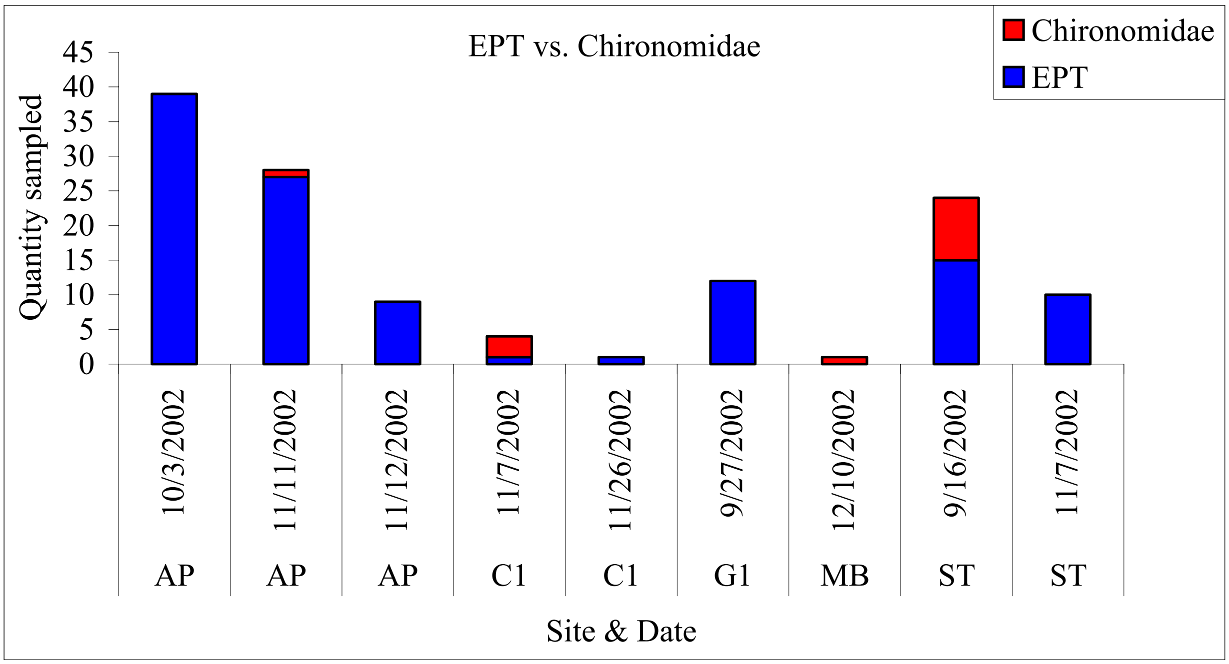
Figure 5.28: Aquatic Macroinvertebrate Taxa



Arroyo Porâ has higher EPT present when compared to the other sites. This is due to higher stream discharge, higher dissolved oxygen concentrations, and perhaps higher substrate diversity. The C1 site has only one of the EPT orders and has more individuals in the Chironomidae family. The next lowest is the Arroyo Mbarakaja (MB) site, which has equal amounts of the Trichoptera and the Chironomidae. The presence of certain aquatic macroinvertebrate orders is important because a site can have high

Shannon diversity with aquatic macroinvertebrate larvae from pollution tolerant orders or families. Two sampling dates are not in figure 5.28 since on these dates none of the aquatic macroinvertebrate taxa of interest were found. Table 5.29 shows the EPT versus Chironomidae.

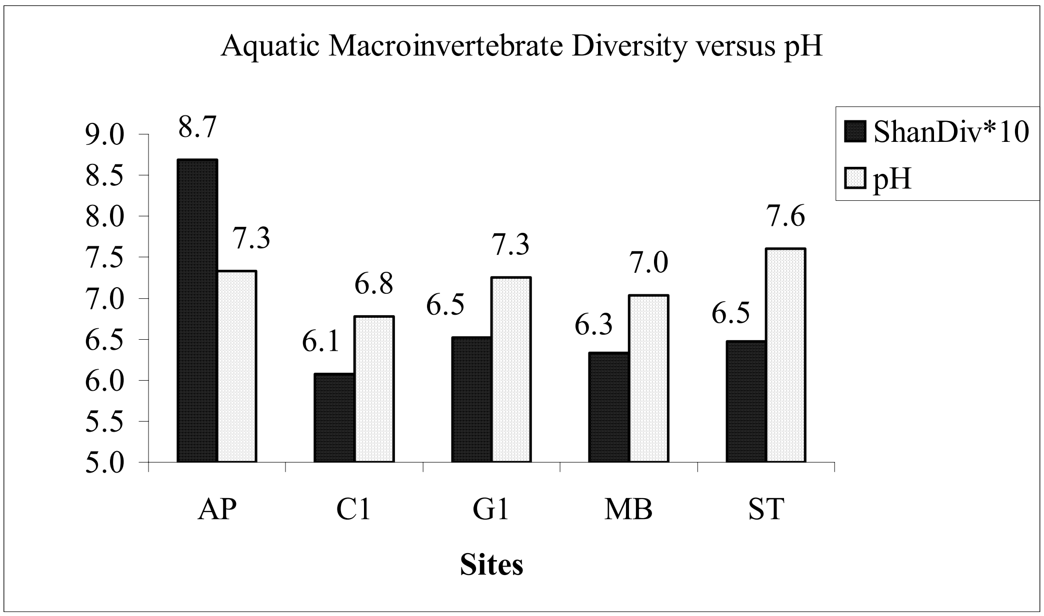
Table 5.29: EPT versus Chironomidae



5.08.4 *Aquatic macroinvertebrates Diversity versus pH*

Low pH resulted in lower aquatic macroinvertebrate abundance according to Hall *et al.* (1980). An experiment was conducted at the Hubbard Brook Experimental Forest in New Hampshire. Acid was added to one stream to maintain the pH at 4.0. It was compared to a reference point where the pH was between 5.7-6.4. Using this paper as reference, perhaps the aquatic macroinvertebrate diversity and abundance in certain sites may smaller due to the lower pH. Figure 5.30 shows the aquatic macroinvertebrate diversity versus pH and the trend is consistent with Hall *et al.* (1980). With an exception of the APU site, the other sites show this trend. The C1 site shows lower pH and lower diversity. Further research can determine if pH is a significant factor in aquatic macroinvertebrate diversity in the Ybytyruzu Mountain Range.

Figure 5.30: Aquatic macroinvertebrate diversity vs pH.



5.09 Conclusions

The importance of riparian buffer zones is crucial to overall stream ecosystem health. The sites with the lowest overstory coverage have low oxygen levels, low aquatic macroinvertebrate diversity, low EPT and imbalance between the Chironomidae and the EPT. C1 and the Arroyo Mbarakaja sites show trends indicating poor water quality. These trends indicate implementation of a land use management plan is pertinent to Santa Catalina.

Chapter 6: Conclusions and Recommendations

Deforestation in Paraguay along riparian zones is a major problem and education about the importance of riparian zones is crucial. The ignorance of scientific management of riparian zones stems from the lack of research and the lack of local knowledge regarding the significance of these ecosystems. Some landowners see the consequences of the deforestation such as erosion and sedimentation of small streams and others do not think of the long-term consequences of their actions. The residents in the Ybytyruzu Mountain Range do not see all the consequences because water flushes out of the system rapidly. Proper management plans of riparian ecosystems can be developed by baseline information from a scientific study.

Riparian buffer zones are crucial to the Ybytyruzu Mountain Range. From the data collected, several trends indicate potential problems. Deforestation of riparian zones destabilizes the stream. Erosion carries away precious soil and nutrients from the farmers' fields. Aquatic macroinvertebrate diversity becomes lower in open canopy versus closed canopy. Santa Catalina is different from most other watersheds in eastern Paraguay because of its nearly pristine watershed. Other communities have more visible degradation of the riparian zones and pollution of streams and rivers.

6.01 *Management Plan*

Recommendations for management of the watersheds in the Ybytyruzu Mountain Range can be implemented in various ways. Peace Corps and the government of Paraguay can use these recommendations to improve the technical aspects of current management plans. Peace Corps trains its agroforestry volunteers to plant trees in farming systems. Peace Corps encourages reforestation in general with no specific plan. Volunteers are expected to establish tree nurseries or promote regeneration of woodlots. Peace Corps could emphasize riparian zones within each of the communities where the volunteers are placed. Training should explain the ecology behind riparian ecosystems and the types of trees found in healthy riparian zones of eastern Paraguay. Some ways of convincing community members to reforest the stream banks is to point out erosion problems and contamination of springs. Paraguayans will understand these problems and will more likely plant trees along these buffer zones. Secondary forest products can be planted in the riparian zone such as fruit trees, fuelwood, and natural herbs. Secondary forest products such as fuelwood can be use sustainable by harvesting selectively. Tree cover should be a useful part of the farming system.

The Paraguayan government and non-governmental organizations can include riparian restoration in their management plans. Several organizations indicated the importance of reforestation for wildlife habitat and corridors for the wildlife to travel. The best way to construct corridors would be reforestation of riparian zones. With definite goals from Peace Corps, NGOs, and the Paraguayan government, the conservation goal can be reached more effectively.

6.02 *Further Research*

Santa Catalina is found in the most beautiful and pristine part of Paraguay. The streams run clear and not long ago the residents of Santa Catalina drank water straight from the stream. Alteration of the riparian zone has degraded the watershed slightly.

Streams and rivers in eastern Paraguay are not as pristine as those found in the Ybytyruzu Mountain Range. Further scientific research can be prepared to analyze the whole Ybytyruzu biome with emphasis on the watershed. A five-year plan should be developed. Data should be gathered on aquatic macroinvertebrate diversity; dissolved oxygen concentrations and pH of stream water; stream discharge, overstory density of the location of aquatic macroinvertebrate sampling and other tests such as phosphorus and nitrogen Analyses. All these data should be collected not only in Santa Catalina but also throughout the Ybytyruzu Mountain Range. It is clear that further research is needed to understand the impacts of the degradation of riparian zones of the Paraguay River Basin.

Further research can aid education programs to be implemented in rural Paraguay. Research can be done at local level by using bio-monitoring techniques or the Paraguayan universities should prioritize research projects based on water quality. On local level elementary schools can teach children to look for important aquatic macroinvertebrates and record them each year. With a combination of reforestation, bio-monitoring and research projects large amounts of data can be gathered and analyzed to continue evolving riparian management plans for Paraguay.

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Appendix 1.01: Raw Overstory Density Values

Lower Arroyo Porâ Percent Overstory Density

Point of Analysis	**Center**	**0m**	**4m**	**8m**	**12m**	**16m**
Transect 1		88.56	73.48	76.08	93.50	70.10
Transect 2		92.20	90.64	92.46	91.68	93.24
Transect 3		35.52	86.22	50.08	18.88	3.54
Transect 4		22.26	51.64	30.58	12.38	0.94
Transect 5	70.62	90.38	94.80	93.24	95.84	95.84
Transect 6	85.44	84.66	42.80	38.38	85.70	80.76
Transect 7	86.48	93.76	90.38	93.50	95.84	95.84
Transect 8	82.84	92.72	43.32	95.06	91.42	96.88
Transect 9	74.52	75.56	81.28	85.44	63.08	5.62
Transect 10		84.66	88.56	94.80	94.80	94.80
Average	79.98	76.03	74.31	74.96	74.31	63.76

Upper Arroyo Porâ

Overstory Density	**Center**	**0m**	**4m**	**8m**	**12m**	**16m**
Transect#1	79.98	89.08	90.64	95.32		
Transect#2	94.54	93.76	96.10	96.88		
Transect#3	90.12	94.80	96.62	95.84		
Transect#4			99.74	98.96	96.36	84.92
Transect#5		98.18	98.70	98.18	94.28	94.54
Transect#6		95.32	95.84	90.90	95.58	93.24
Average	88.21	94.23	96.27	96.01	95.41	90.90

C1 Site

Overstory Density	Center	0 meters	4 meters	8 meters	12 meters	16 meters
Transect 1		49.30	81.02	1.20	0.16	0.16
Transect 2		1.20	7.96	12.90	71.92	11.08
Transect 3		98.80	92.04	87.10	28.08	88.92
Transect 4		52.42	93.50	94.02	49.04	23.82
Transect 5	20.96	68.02	47.22	8.48	3.02	1.72
Transect 6		9.52	3.28	2.76	34.48	2.76
Transect 7	91.68	91.42	94.54	6.40	0.16	0.16
Transect 8		97.14	97.66	94.54	43.58	1.20
Transect 9	57.36	62.82	89.08	92.72	70.88	7.18
Transect 10		58.92	15.76	0.16	0.16	0.16
Transect 11	94.80	95.06	95.84	96.88	92.46	73.22
Transect 12		94.02	86.22	0.16	0.16	0.16
Transect 13	93.50	96.36	92.98	91.16	97.92	97.92
Transect 14		93.76	94.02	94.54	25.38	0.16
Transect 15	95.06	95.84	95.58	90.12	7.70	0.16
Transect 16		95.06	69.84	3.28	0.16	0.16
Average	75.56	72.48	72.28	48.53	32.83	19.31

Appendix 1.01 continues on next page

Appendix 1.01 continued
G1 Overstory Density

	Center	0 meters	4 meters	8 meters	12 meters	16 meters
Transect 1		81.02	62.3	13.42	48	79.46
transect 2		91.16	92.72	92.72	96.62	96.36
transect 3		94.54	96.62	94.8	91.16	84.66
transect 4		91.68	95.06	95.58	90.12	76.86
transect 5	89.08	91.16	66.46	87.78	74	74.26
transect 6		89.86	78.42	90.9	79.98	82.06
transect 7	92.2	93.24	92.46	96.88	93.24	92.46
transect 8		93.24	89.6	94.02	84.92	92.2
transect 9	91.16	93.24	90.38	92.72	96.62	94.02
transect 10		92.46	84.14	84.92	86.22	89.08
transect 11	89.6	90.9	91.42	95.58	90.9	91.68
transect 12		92.98	92.2	91.42	93.5	93.5
transect 13	93.76	93.76	89.6	92.2	91.68	90.9
transect 14		90.9	84.66	95.58	93.5	89.34
transect 15	87.78	87.78	91.94	89.6	89.34	
transect 16		83.36	78.42	82.32	79.46	80.5
Average	90.60	90.71	86.03	86.90	86.20	87.16

Appendix 1.01 continue next page

Appendix 1.01 Continued

Overstory Density Data for Mbarakaja Stream Site						
Transect	**center**	**0 meters**	**4 meters**	**8 meters**	**12 meters**	**16 meters**
Transect 1		92.98	89.08	95.58	52.16	13.16
Transect 2		85.44	93.50	61.78	92.60	22.39
Transect 3		94.54	95.32	93.76	83.88	58.14
Transect 4		92.46	95.84	96.62	68.54	29.80
Transect 5		88.56	14.46	0.16	65.42	0.16
Transect 6		64.12	15.24	0.16	0.16	0.16
Transect 7		63.34	82.32	12.12	0.42	5.10
Transect 8	71.66	70.88	70.88	9.09	0.0016	0.0744
Transect 9		6.75	0.16	0.16	0.16	0.16
Transect 10	89.08	93.24	9.61	94.28	7.01	1.68
Transect 11		88.82	17.84	0.68	0.16	0.16
Transect 12	36.82	30.32	0.42	0.16	0.16	0.16
Transect 13		44.10	0.16	0.16	0.16	0.16
Transect 14	32.4	78.16	4.32	1.20	3.54	1.46
Transect 15		0.18	0.94	0.42	0.16	0.16
Transect 16		16.02	0.16	0.16	0.42	0.16
Average	**57.49**	**67.00**	**42.30**	**34.27**	**27.39**	**9.72**

ST Overstory Density						
Transect	**Center**	**0m**	**4m**	**8m**	**12m**	**16m**
Transect 1	90.38	27.72	4.32	0.94	0.16	0.16
Transect 6	55.80	53.20	31.62	64.90	0.16	0.16
Transect 9	52.68	59.70	59.70	25.90	1.20	0.16
Transect 8	79.98	59.96	42.80	3.02	0.16	0.16
Transect 2	81.54	92.98	22.52	12.12	0.16	0.68
Transect 3	86.22	36.30	11.86	1.20	1.72	3.28
Transect 5	13.94	16.28	16.80	2.24	12.12	8.48
Transect 4	75.04	19.40	75.56	95.06	70.10	48.00
Transect 15		58.92	54.50	52.68	85.44	52.68
Transect 14	36.56	43.06	89.60	83.62	84.66	80.50
Transect 13	89.86	86.22	92.46	95.32	98.44	82.84
Transect 10	64.64	75.82	88.56	83.88	89.34	92.98
Transect 7	50.08	78.94	79.72	85.18	95.58	93.50
Transect 11	76.34	88.56	93.76	97.92	97.92	97.92
Transect 12		92.98	96.36	97.92	97.92	97.92
Average	65.62	59.34	57.34	53.46	49.01	43.96

Appendix 2.01: Chemical analyses data

Arroyo Porâ lower sites

Site	Date	pH	Dissolved oxygen
APM	12-Aug-01	7.4	8.4
APL	01-Sep-01	7.3	3.1
APM	05-Nov-01	7.4	7.1
APM	16-Nov-01	7.4	7.6
APM	12-Feb-02	7.4	8.3
APL	22-Mar-02	7.0	7.1
APM	10-May-02	7.4	8.9
APM-S	04-Sep-02	7.6	n/a
APL	9-Nov-02	7.5	7.3
APL	9-Nov-02	7.3	8.0
APL	9-Nov-02	7.2	8.0
APL	9-Nov-02	7.1	8.5

Upper Arroyo Porâ

Stream/site	Date	pH	Oxygen (ppm)
APU	18-Aug-01	7.1	5.6
APU	17-Nov-01	7.2	7.6
APU	23-Mar-02	7.0	5.8
APU	09-Aug-02	7.1	7.1

C1 site

Stream/site	Date	Oxygen (ppm)	pH
C1	5-Mar-02	4.9	6.9
C1-a	7-Nov-02	4.0	6.8
C1-b	7-Nov-02	4.7	6.9
C1-c	7-Nov-02	5.2	6.8
C1-d	7-Nov-02	5.9	6.5

Appendix 2.01 continues next page

Appendix 2.01 Continued

G1 site

Site	Date	pH	Dissolved Oxygen
G1	1/28/2002	7.2	7.05
G1	5/6/2002	7.3	8.05
G1-a	7/13/2002	7.6	n/a
G1-b	7/13/2002	7.4	n/a
G1-c	7/13/2002	7.2	n/a
G1-d	7/13/2002	7.1	n/a
G1-e	7/13/2002	6.9	n/a
G1-f	7/13/2002	7.3	n/a
G1-g	7/13/2002	7.3	n/a
G1	9/17/2002	7.4	6.6
G1-1	11/7/2002	7.0	6.2
G1-2	11/7/2002	7.4	6.4
G1-3	11/7/2002	7.1	6.8
G1-4	11/7/2002	7.3	5.4

Arroyo Mbarakaja

Date	pH	Dissolved Oxygen
6-Aug-01	6.9	6.8
14-Oct-01	7.0	6.0
13-Feb-02	7.5	8.2
5-Jun-02	7.1	7.2
22-Oct-02	6.9	7.1
4-Nov-02	6.9	5.9
4-Nov-02	6.9	5.3
4-Nov-02	7.1	n/a

Appendix 2.01 Continues next page

Appendix 2.01 Continued

ST site

Site	Date	pH	Dissolved oxygen
ST	29-Jan-02	7.1	8.6
ST	9-May-02	7.4	7.1
ST-1	13-Jul-02	7.7	n/a
ST-2	13-Jul-02	7.6	n/a
ST-3	13-Jul-02	7.8	n/a
ST-4	13-Jul-02	7.8	n/a
ST-5	13-Jul-02	7.8	n/a
ST-6	13-Jul-02	7.8	n/a
ST	16-Sep-02	7.6	6.1
ST	17-Oct-02	7.7	7
ST-a	7-Nov-02	7.4	6.5
ST-b	7-Nov-02	7.6	6.4
ST-c	7-Nov-02	7.6	

Appendix 3.01 Stream Volume

Stream	Date	Vol of water m3/s
AC	9-Jun-01	0.997
AG	11-Jun-01	0.594
APL	8-Jun-01	0.737
APL	1-Sep-01	0.039
APL	1-Sep-01	0.036
APM	2-Sep-01	0.037
APM	5-Feb-02	0.088
APL	8-Feb-02	0.265
APM	10-May-02	0.087
APM-S	4-Sep-02	0.119
APL	11-Nov-02	4.999
APM-S	2-Dec-02	0.519
APU	9-Aug-02	0.029
B1 & B2	5-Feb-02	0.078
C1	15-Feb-02	0.022
C1	16-May-02	0.016
C1	7-Nov-02	0.008
C1	7-Nov-02	0.005
C1	2-Dec-02	0.054
G1	28-Jan-02	0.007
G1	29-Jan-02	0.200
G1	6-May-02	0.011
G1	20-May-02	0.086
G1	17-Sep-02	0.009
G1	8-Nov-02	0.006
MB	3-Sep-01	0.007
MB	13-Feb-02	0.016
MB	5-Jun-02	0.007
MB	22-Oct-02	0.002
MB	25-Nov-02	0.079
MB	15-Oct-01	0.013
ST	29-Jan-02	0.850
ST	3-May-02	0.017
ST	5-Sep-02	0.018
ST	8-Nov-02	0.034

Appendix 3.02 Physical Characteristics

Arroyo Porâ lower

Stream	Date	Air Temp	Water temp	Avg Width (m)	Avg Depth (m)	Velocity m/s	Vol of water m^3/s
APM	8-Jun-01	17	18.75	7.167	0.182	0.564	0.737
APL-deepwater	1-Sep-01	28	21	6.886	0.421	0.013	0.039
APL-shallow water	1-Sep-01	28	21	2.903	0.018	0.712	0.036
APM	2-Sep-01	26	22	5.429	0.133	0.051	0.037
APM	5-Feb-02	26	22.5	4.543	0.207	0.094	0.088
APL	28-Jan-02	32.5	22.5	6.638	0.642	0.062	0.265
APM	10-May-02	24.5	21	4.770	0.194	0.094	0.087
APM-S	4-Sep-02	19	12	3.528	0.129	0.263	0.119
APM-S	2-Dec-02	27		4.443	0.205	0.570	0.519

Upper Arroyo Porâ

Stream	Date	Air Temp	Water temp	Avg Width (m)	Avg Depth (m)	Velocity m/s	Vol of water m^3/s
APU	23-Mar-02	26	22.5	75cm-200cm	n/a	n/a	na/
APU	9-Aug-02	18.5	17	1.729	0.0723	0.228636223	0.029

C1 site

Stream	Date	Air Temp	Water temp	Avg Width (m)	Avg Depth (m)	Velocity m/s	Vol of water m^3/s
C1	15-Feb-02	29	23	1.522	0.246	0.058	0.022
C1	16-May-02	27	22	1.162	0.088	0.162	0.016
C1-a	7-Nov-02	35	23	1.089	0.093	0.078	0.008
C1-b	7-Nov-02	29	21.5	0.694	0.073	0.102	0.005
C1	02-Dec-02	27.5	25	1.111	0.123	0.395	0.054

G1 site

Stream	Date	Air Temp	Water temp	Avg Width (m)	Avg Depth (m)	Velocity m/s	Vol of water m^3/s
G1	28-Jan-02	31	23	0.64790909	0.0895	0.114186971	0.007
G1	29-Jan-02	23	22	1.73466667	0.1529	0.752292721	0.200
G1	6-May-02	22.5	20.5	0.7141	0.0947	0.114186971	0.008
G1	20-May-02	17	20	1.314	0.134	0.488269616	0.086
G1	17-Sep-02	28	22	0.588	0.0862	0.175290001	0.009
G1	8-Nov-02	26	19	0.663	0.0843	0.105462746	0.006

Appendix 3.02 continues on next page

Appendix 3.02 Continued

Arroyo Mbarakaja

Stream	Date	Air Temp	Water temp	Avg Width (m)	Avg Depth (m)	Velocity m/s	Vol of water m^3/s
MB	7-Jun-01	18	19.5				
MB	3-Sep-01	31	22	1.330	0.058	0.090	0.007
MB	15-Oct-01	27	20	0.453	0.104	0.275	0.013
MB	13-Feb-02		22	1.102	0.126	0.115	0.016
MB	5-Jun-02	26	20	1.190	0.178	0.032	0.007
MB	22-Oct-02	18	20	0.962	0.108	0.019	0.002
MB	25-Nov-02	32	23.5	1.063	0.093	0.796	0.079

ST site

Stream	Date	Air Temp	Water temp	Avg Width (m)	Avg Depth (m)	Velocity m/s	Vol of water m^3/s
ST	29-Jan-02	23	22	4.0325	0.26	0.810684114	0.850
ST	3-May-02	25.5	18	0.8853	0.1192	0.160696657	0.017
ST	5-Sep-02	31	15	0.8507	0.1331	0.161570211	0.018
ST	8-Nov-02	30	21	0.8225	0.1152	0.353675979	0.034

Appendix 4.01 Insect Diversity

Site	Date	Species	Individuals	Shannon-Weaver
APM	11/5/2001	12	32	0.8532
APL	11/10/2001	15	40	1.0086
APU	11/17/2001	4	7	0.5546
APM-s	10/3/2002	11	61	0.9722
APL	11/11/2002	10	48	0.8163
APM-S	11/12/2002	8	23	0.6937
Cazal	11/8/2001	7	19	0.7282
Cazal	11/7/2002	9	24	0.7480
Cazal	11/26/2002	3	7	0.3458
G1	9/15/2001	10	26	0.9157
G1	11/6/2001	6	26	0.6199
G1	9/27/2002	6	24	0.6148
G1	11/7/2002	4	10	0.4581
MB	10/15/2001	7	26	0.5888
MB	12/10/2002	5	6	0.6778
ST	11/7/2002	4	14	0.5191
ST	9/16/2002	9	24	0.7764

Arroyo Pora

Arroyo Pora Lower (APL)	**November 10, 2001**		
Animals caught	Quantity	Family	Order
Crayfish	1		Crustaceans
Round Crab	3		Decapoda
Red larvae	1	Chironomidae	Diptera
clear larvae	2.		Diptera
green larvae	1		Diptera
Mayfly	4		Ephemeroptera
Green caddisfly Larvae	13		Trichoptera
Black caddisfly larvae	2.		Trichoptera
Gray caddisfly larvae	1		Trichoptera
Orange Caddisfly larvae	2		Trichoptera
Damselfly Clubtail black	1		Odonata
Dragonfly (tubetail)	2		Odonata
Damselfly Clubtail (beige)	1		Odonata
Astynax spp	4		Charicidae
Scavenger beetle	2		Coleoptera
Total	40		

Appendix 4.01 continues on next page

Appendix 4.01 continued

APM-s	**3-Oct-02**	
Insects		
Animals caught	Quantity	Order
larvae Unidentifiable	8	Diptera
Land beetles	3	Coeloptera
Aquatic Centipede	1	Chilopoda
Caddisfly nymphs	16	Tricoptera
common Mayfly nymps	20	Ephmeroptera
damselFly	3	Odonata
Dragon fly	2	Odonata
earthworm?	3	Diptera
Water Penny	1	Coeloptera
Stonefly	3	Plecoptera
Giant larvae	1	diptera?
Total	61	

Arroyo Pora mid			
Date: November 5, 2001			
Animals caught	**Quantity**	**Family**	**Order**
Water Penny	1	Psephenidae	Coleoptera
Clear larvae	1		Diptera
Larvae	4		Diptera
Caddisfly	2		Trichoptera
Astyanax sp.	2	Characidae	
tigerfish	1		
tiny oval beetle	1		Coleoptera
red larvae	2		Diptera
black larvae	14		Diptera
damselfly	2		Odonata
green caddisfly	1	Rhyacophilidae	Trichoptera
crab round	1		Decapoda

APL- 11/11/02			
Animals caught	Quantity	Family	Order
Congrejo	2		Decapoda
Mayfly	26		Ephemeroptera
larvae	2		Diptera
Red larvea	1		Diptera
Damselfly	3		Odonata
Beetle	3		Coeloptera
Dragonfly	3		Odonata
Caddisfly	1		Tricoptera
waterpenny	3		Coeloptera
green congrejos	4		Decapoda
Total	48		

Appendix 4.01 Continues on next page

Appendix 4.01 continued

APM-S 11/12/2002		
Animals caught	Quantity	Order
Larvae	5	Diptera
White caddisfly	2	Trichoptera
Congrejo	2	Decapoda
Clubtail	2	Odonata
Damselfly	2	Odonata
Mayfly	7	Ephemeroptera
Catfish-baby	1	
Waterpenny	2	Coeloptera

Site: Arroyo Pora upper	**Date November 17th, 2001**	
Animals caught	Quantity	Order/class
Crab (round) light color	2	Decapoda
dragonfly nymph	3	Odonata
damselfly nymph	1	odonata

C1-11/8/2001			
Animals caught	Quantity	Family	Order
crabs	4	Decapoda	Arthopoda
red larvae	5	Chironomidae	Diptera
clear larvae	2		Diptera
diving beetle	1		Coleoptera
black mayfly	3	Caenidae	Ephemeroptera
dragonfly	2		Odonata

C1- 11/7/2002			
Animals caught	Quantity	Family	Order
congrejo	7		Decapoda
damselfly	8		Odonata
Caddisfly	1		Tricoptera
Red larvae	1		Diptera
beetle	3		Coleoptera
strange beetle	1		Coleoptera
white larvae	1		Diptera
Ancistrus sp	2		

Appendix 4.01 continues on next page

Appendix 4.01 continued

C1- 11/26/2002		
Animals caught	Quantity	Order
crab	1	Decapoda
clubtail	5	Odonata
mayfly	1	Ephemeroptera

Nov. 6th 2001			
Site G2			
Animals caught	Quantity	Family	Order
Clams	12		
Crabs	7	Decapoda	
diving beetles	2	Dytiscidae	Coleoptera
crayfish	2	Decapoda	
Dragonfly	2		Odonata
Mayfly	1		Ephemeroptera

G1 09/15/01		
Animals caught	Quantity	Order
Crabs	6	Decapoda
dragon fly nymph-tube tail	4	Odonata
Damsel fly	2	Odonata
Water Beetle	1	Coleoptera
Fan-tail nymph	2	Odonata
Red larvae	5	diptera
larvae	2	diptera
water spider	1	Archanid
small beetle	2	Coleoptera
medium beetle	1	Coleoptera

G1-11/7/2002		
Animals caught	Quantity	order
congrejo	4	Decapoda
Dragonfly	2	Odonata
Damselfly	4	Odonata

Appendix 4.01continues on next page

Appendix 4.01continued

MB 10/15/01		
Animals caught	Quantity	Order
Clubtail	15	Odonata
Caddisfly	1	Trichoptera
Crayfish (alacran	4	Decapoda
Crab (round)	3	Decapoda
Caddisfly small	1	Trichoptera
Darner	1	Odonata
Scavenger Beetle	1	Coleoptera

Arroyo Mbarakaja	**10-Dec-02**	
Animals caught	Quantity	Order
small crab	2	Decapoda
damselfly nymph	1	Odonata
dragonfly nymph	1	Odonata
red larvae	1	Diptera
unknown larvae	1	Diptera

ST-11/7/2002		
Animals caught	Quantity	Family/order
Damselfly	3	Odonata
Dragonfly	1	Odonata
Mayfly	3	Ephermeroptera
Caddisfly	7	Tricoptera

ST-09/16/02		
Animals caught	**Quantity**	**Order**
Round crab	4	Decapoda
Oval Crab	1	Decapoda
Mayfly	5	Ephermeroptera
Water Penny	1	Coleoptera
Red larvae	9	Diptera
Damselfly	1	Odonata
Clubtail	1	Odonata
black fly nymph	1	Diptera
Arachnid	1	

APM November 16, 2001	
Animals caught	Quantity
Astyanax sp.	17
Crayfish/freshwater shrimps	6
catfish	3
Crab (round)	1
Water spider	1

APM September 16,2001	
Animals caught	Quantity
Crabs	3
crayfish/freshwater shrimp	9
Astyanax sp.	36
tadpoles	13
diving beetle	1
tigerfish	2
catfish	4

APL 3/23/02		
Animals caught	Quantity	Family
Catfish	1	
oval Crab	1	
Round crab	7	
Crenicichla lepidota	2	Cichlidae
beetle	9	
Ancistrus sp.	1	Loricariidae
Astyanax sp.	26	Characidae
Total	47	

Appendix 4.04 continues on next page

Appendix 4.04 continued

12-Dec-02	
APM-s	
Animals caught	Quantity
Ancistrus sp.	1
Astyanax sp.	4
catfish	8
chiclid	1
tigerfish	1
congrejo	2
Total	17

APL 11/12/02	
Fish	
Animals caught	**Quantity**
Ancistrus sp.	5
Catfish	5
round crab	3
Large diving beetle	1
Turtle	1
Oval crab	2
Tiger fish	1
Total	18

Site APM-S		
Date: October 3, 2002		
Animals caught	Quantity	Family
Astyanax sp.	14	
Ancistrus cirrhosus	1	
Crenicichla spp?	1	chiclid
Crab	1	
Total	17	

Appendix 4.04 continues next page

Appendix 4.04 continued

APL-10/04/02	
Animals caught	**Quantity**
Spotted catFish	1
common catfish	14
turtle	1
Ancistrus cirrhosus	6
Crenicichla lepidota	1
Congrejo	8
total	31

Site: Arroyo Pora mid S	
Date: 9/27/02 & 9/28/02	
Animals caught	**Quantity**
Ancistrus cirrhosus	5
Astyanax sp.	10
Catfish	7
Crenicichla lepidota	1
Total	23

November 11, 2001		
Animals caught	**Quantity**	**Family**
Round Crab	9	
Oval Crab	2	
Crayfish	9	
Astyanax sp.	9	Characidae
Catfish	2	
Ancistrus sp.	5	Loricariidae
Crenicichla lepidota	1	Cichlidae

Fish Traps	
MB 10/15/2001	
Animals caught	Quantity
Crayfish (alacran)	16
Crab (oval)	1
Crab (round)	2
Cat Fish (Alurundi'a po'I)	2
Astyanax sp.	32

Appendix 5.01

Survey of streams

11. Name of family, hectares, and crops
12. Where do you get your potable water? What happens during drought?
13. Where do you get firewood?
14. How meters away?
15. What are the major problems within your property?
16. Where does the soil go when it is eroded away?
17. Where are there streams on your property?
18. What do you use the streams for?
19. What are the uses of the land surrounded the streams?
20. How have the streams changed since you have been here in Santa Catalina?

a. Name of family: 1
Hectares:>5
Crops: Sugar cane, mandioca, beans, corn
This family has well near the house that is used for their drinking water. The well was dug through bedrock. They get their firewood in the woodlot near their home. There are no problems with there property and there are no streams in their property.

b. Name of family: 2
Hectares:>20
Crops: organic Sugar cane, corn, mandioca,
This family has the well near the house that also was dug through stone. When there is a drought they retrieve water from a spring about 200 meters from the house. They retrieve firewood from a nearby woodlot about 20 meters from the house. Senor Cazal finds no problems with his property. There two springs that become streams within the property. These springs are surrounded by forest. They don't use the streams for anything and they realize that if the forest around the springs/streams were eliminated the springs would dry up.

3 Name of Family: 3
Hectares: 10-20
Crops: Sugarcane, mandioca, corn, and beans
The well is near the house and during drought they need to retrieve water 100 meters from the house in a spring. There firewood is retrieved 50meters from the house. They have no problems with their property. There are no streams on their property.

4 Name of Family: 4
Hectares: >20
Crops: Sugar cane 12 hectares, mandioca, corn, yerba mate, and onions
This family has two wells one is closer to the house than the other. They retrieve firewood from their woods about 700 meters from the house. They have no problems with their property. They have one stream on their property and one side has farmland on it and the other side has woods. They do not rotate their crops.

5 Family Name: 5
Hectares: 10-20
Crops: sugar cane mandioca, corn, cotton, beans,
Their well is 6meters form the house. They retrieve firewood 100meters in their woodlot. They have no problems with their property. There is one stream that is surrounded by forests. The water is worse now that when they first arrived.

Appendix 5.01 Continues on next page

Appendix 5.01 continued

6 Family Name: 6
Hectares: <5
Crops: corn and mandioca. They own the general store and sell meat.
They have a well that they pump water out to get running water. They buy their firewood from neighbors.

7 Family Name: 7
Hectares: >20
Crops: corn, mandioca, and beans
This family retrieve their water from Martinez, 100meters from house. There is one s tream about 400 meters from house and it has not changed in the last 27 years.

8 Family Name: 8
Hectares: >20
Crops: Sugar cane, cotton, corn, mandioca, onions,
Their well is next to the house and it is 12 meters in depth, during droughts they must go to the spring which is about 100 meters from the house. They get their firewood from the woods 500 meters from the house.
The problems with their property is low nutrients in some areas depending on soil type. There is one stream on their property and both sides are forested between 10m to 200 meter buffer zone. They have been on the property for 40 years and the changes in the stream has been slightly smaller and deforestation.

9 Family Name: 9
Hectares: >30
Crops: Sugar cane, cotton, corn, mandioca and beans
They have a deep well which does not dry up. They retrieve firewood 500 meters from their house The problems with their property are low nutrients in some areas and erosion in the same areas. The soil enters into a small stream that is slowly drying up. There is another stream on the property as well that is near Family #10 property. The one stream near the house has sugar cane on one side and a little of forest on the other side. They use the stream to wash clothes

10 Family name: 10
Hectares: >20
Crops: Mandioca, corn, onions, bananas, cotton, peanuts, sweet potato, beans, oranges, mandarins, avocado, garlic, herbal remedies, carrots, green onions
This family has a well in their house that was dug through rock and does not dry up during droughts. The retrieve firewood in their woods 200 meters from house. The problems with their property is erosion. There are no streams on property.

11 Family Name: 11
Hectares: >20
Crops: Sugar cane, peanuts, beans, cotton, corn,
The well is 50 meters from house it is constructed from a spring. They retrieve firewood near their home 25 meters from the house. There are no problems with their property. They have one stream on their property and it is surrounded by forest . They use the stream to wash clothes.

12 Family Name: 12
Hectares: <20
Crops: Sugar cane, mandioca, corn
There is a spring near the farmland. This family does not live on their property. They retrieve firewood about 5 kilometers form house. The property has problems with low

nutrients and erosion. The soil enters the stream. There are two streams on his property. The streams have a little of buffer zone but is surrounded by farmland